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THE DEVELOPMENT OF MODERN ROAD SURFACES.

BY
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THE development of the road surfacing of the present day has undoubtedly been entirely due to the introduction of the automobile, with its astonishingly widespread and general use and the rapid increase in its power and speed. We will, however, first briefly review the development of the earlier roads.

It has been said that the condition of a nation's roads is a measure of its development, and, in general, history has borne this out.

We know that the Incas, in Peru, have left us the remains of some wonderful pieces of road engineering, while the remains of a stone tramway, used probably in the construction of the pyramids in Egypt about 4000 B.C., is the earliest road to which we can assign a definite date.

While the Greeks paid a great deal of attention to their roads, the Carthagenians, who flourished from 1200–835 B.C., were the scientific and systematic road builders. From them the Romans learned the art, and their magnificent system of roads

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connecting all parts of the Roman Empire attested to their ability. This was undoubtedly the most extensive system of national roads that the world has ever seen; it included in all about 50,000 miles of road, and it has furnished the foundations for the road systems of continental Europe.

While the Romans did not show the engineering ability of the Incas in locating their roads, or the skill of the Carthagenians in the surface finish, yet their work was wonderfully and substantially done. In general, their roads were about 16 feet wide and were made of four courses—in all about 3 feet thick. The foundation consisted of two courses of large, flat stones laid in lime mortar; the sub-base, a 3 to 1 concrete of broken stones and lime, well tamped; a filler course of broken bricks and other rubbish mixed with lime, on which was laid the wearing surface, made of irregularly shaped stone blocks about six inches thick, joined and fitted very carefully. These roads were a bit rough, but they safely bore the enormous weight of the obelisks and statues that were brought over them into Rome.

With the fall of the Roman Empire the roads fell into ruin from neglect, and in some cases were even destroyed as a safeguard against pillagers, so that through the Dark Ages and well up to the middle of the Eighteenth Century, the so-called roads were little better than rough trails passable only in good weather.

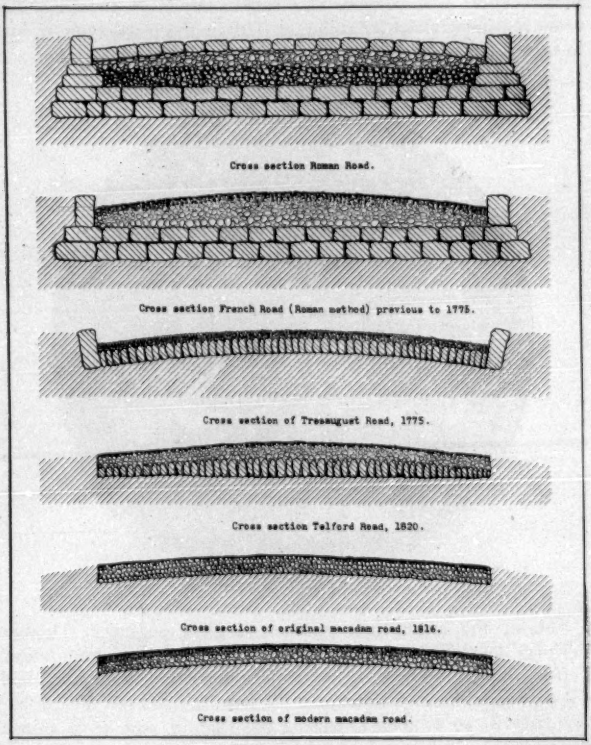
The question of the improvement of the streets in the larger cities was the first step in the reawakening of the interest in road building. The streets were usually in very bad condition, filled with mud and filth of every description.

In 950 the streets of Cordova, Spain, were paved; Paris followed in 1184; London in 1417. In general, a very rough stone block was used with little attention to the foundation.

The French seem to have been the first to have taken up again the science of road making. Beginning in 1661, under Louis XII, they built about 15,000 miles of stone road under the system of forced labor called the "corvée," which almost caused a revolution. Napoleon, however, laid the real foundations for the present system of roads, by putting them under the care of a national corps of Engineers of Bridges and Roads, whose members were educated at the expense of the state. This progress was marked by a very valuable report in 1775 by Tresauget, an engineer of the district of Limoges, who pointed

out the necessity for a firm foundation, which he built on a cambered surface, of large flat blocks of stone set on edge by hand, firmly bonded into place with small stones and spalls.

FIG. 1.

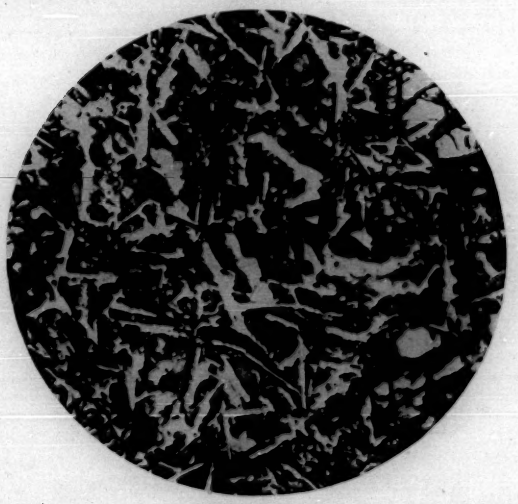

Cross section Roman Road.
Cross section French Road (Roman method) previous to 1775.
Cross section of Tressuguet Road, 1775.
Cross section Telford Road, 1820.
Cross section of original macadam road, 1816.
Cross section of modern macadam road.

Development of broken stone roads.

In 1819 John L. Macadam, an English road engineer, developed a different idea, in that he claimed that a solid foundation was not essential, but even injurious. He held that the

ground would carry the load if it was properly spread over the whole area of the road and kept dry. Macadam made the foundation entirely of broken stone, no piece of which was to weigh over 6 ounces, which would be equivalent to about 2½ inches stone, and covered this with a layer of smaller stones rendered impervious by rolling. This is the usual type of road in use to-day.

FIG. 2.



Basalt (trap).

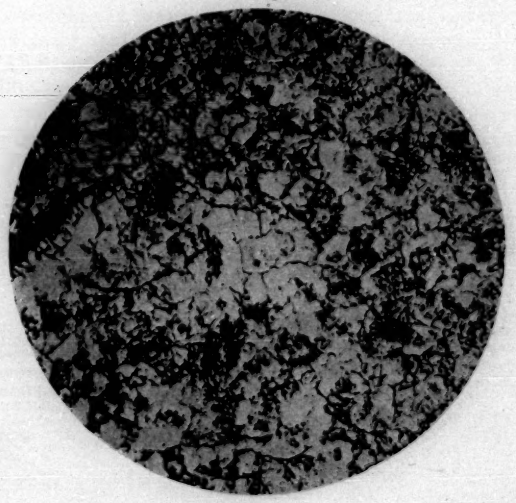
About the same time another English engineer, Thomas Telford, developed the old Tresauget idea of a rigid foundation. Telford built his lower course as Tresauget did, with hand-laid slabs on edge, but laid them on a flat base and secured the camber by using 8- to 10-inch stones in the middle, and 4- to 6-inch stones at the gutter.

These two types of road construction have been universally adopted, and both have their advocates. It seems that the Telford construction is somewhat more expensive than the Macadam, but is more successful in poor ground. The rigid

foundation, however, seems in some cases to act as an anvil, crushing the wearing surface more quickly, and thus resulting in a shorter life to the surfacing material.

These two men seem to have developed all that was necessary in stone road construction; though many modifications have been made in the original methods they have only been those necessary to adapt them to varying conditions and ma-

FIG. 3.



Limestone.

terials, and the future developments were in the use of other materials for special purposes.

The terms Macadam and Telford are now used so indiscriminately, and through changes and modifications in the older methods they have so lost their original significance, that I feel the generic term of broken stone road is much to be preferred in describing such surfaces. As this type of road is the basis of our present system of improved roads, we will examine it more closely.

In general, we will have the body of the road transmitting and distributing over the foundation the concentrated loads from the traffic. The body is then made of comparatively large sizes of broken stone. This is usually laid in one or more layers for ease in rolling, and it is customary to add a little fine stone to act as a binder, and thus aid in compacting. Since the body of the road can only receive the vertical load the binder is not

FIG. 4.

Granite.

really essential, as the maximum load that it will probably be called upon to bear was applied by the roller during its construction.

The surface layer, however, must perform a double function. It must resist the vertical load and varying strains introduced by the traffic while remaining intact. This is essential in preventing an excess of moisture reaching the bottom of the road, and thence to the foundations, which would result in some disintegration from the moisture itself; but principally it would result in

softening and sinking of the body of the road into the foundation, and also render the road liable to destructive lifting action due to frost.

The continuity of this wearing surface is dependent upon several properties of the stone—its hardness, or the power to resist abrasion due to traffic, toughness or resistance to fracture from shocks, and the cementing or binding power, which is the property possessed by the rock dust after being wet, of acting as a cement and binding the coarser particles in the surface together, thus forming an impervious layer over the road and permitting the wearing surface to perform its proper functions.

The binding or cementing value is probably the most important property of the road metal, as its existence is absolutely essential to the success of the road. The following extract from a table published by the Office of Public Roads gives the values of these different properties for some of the commoner rocks used in road building:

CHARACTERISTICS OF ROAD METALS.

	Hardness.		Toughness.		Cementing Value.	
	Max.	Min.	Max.	Min.	Max.	Min.
Basalt (trap)	19.2	5.9	39	6	500+	4
Diabase (trap)	19.2	12.8	54	4	500+	2
Chert	19.7	12.7	26	5	106	4
Dolimite	18.3	4.4	27	4	179—	9
Limestone	19.1	0	25	2	500+	10
Quartzite	19.7	16.5	30	5	45	0
Sandstone	19.5	0	60	2	500+	3
Granite	19.2	13.6	31	2	255	3

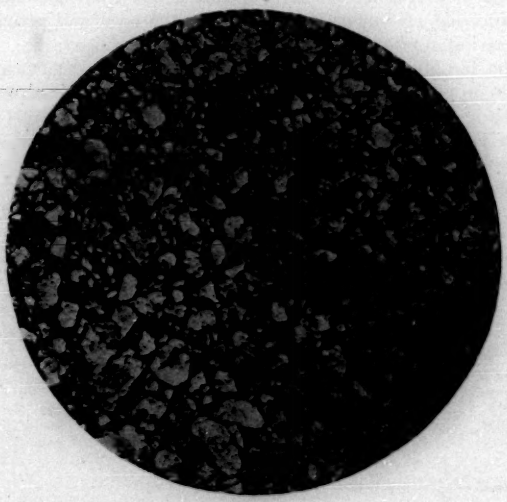
These results are interpreted as follows:

Hardness.....Soft—14	Medium.....14— 17	Hard..... 17+
Toughness.....Low—14	Medium.....13— 19	High..... 19+
Cementing value..Low—10	Fair.....10— 25	Good..... 26—75
	Very good...76—100	Excellent..100+

The moisture content in Macadam roads is an exceedingly important factor in its condition and life. Many rocks do not develop their full cementing power until they have been thoroughly moistened for several days to a week, so that in the construction of roads it is exceedingly important that ample water should be supplied during the rolling. In order that this cementing bond may be retained and its full strength developed, it is

quite essential that some moisture should always be present in the surface of the road, otherwise, especially with certain classes of rocks, the bond is lost entirely when the surface becomes dry, and in general it is weakened to a considerable extent. In this connection, we must remember that the surface of a Macadam road is constantly being worn away and reformed by the grinding action of the steel tires of the traffic, bringing fresh portions

FIG. 5.



Quartzite.

of the rock dust into play to replace those lost by the effects of wind, rain and traffic. While we desire, and must have, a certain amount of moisture in the surface of the road, yet it is exceedingly important that this moisture should be kept from the foundation for the reasons that were explained above.

The question of moisture is exceedingly important in all roads, as even the common clay or dirt road, if properly dragged and containing sufficient moisture to develop the plastic properties of the clay to just the right extent, will yield an exceedingly

smooth and resilient surface, pleasant to drive over and amply strong to resist the ordinary farm traffic. Unfortunately, however, the effect of moisture is so important that a very small variation either way renders the road either muddy and full of ruts or very dusty.

Thus, the theory of the broken stone road requires that the fine powder that is ground from the wearing surface shall furnish the cementing bond between the stone particles composing it. Under theoretical conditions, this wear should just equal the amount removed by the traffic, wind, and rain, so that the surface voids should always remain filled. Practically, however, the rock must be somewhat softer so that there will be an excess of dust powder always present. On the other hand, as is seen in even an asphalt street where no dust is made by the surface, there is a constant accumulation, from the surroundings and the traffic, of a considerable quantity of detritus, which under the action of the traffic is ground into dust.

We may thus classify this phenomena into two classes. Preventable, as applying to that due to the road surface, and unavoidable, that due to the traffic. The following table gives the quantity of dust removed from different classes of pavements in cubic yards per day from 1000 square yards of road surface:

Kind of surface.	Dust, cu. yds. per day.
Asphalt	.007–.04
Wood block	.04 –.07
Granite	.07 –.25
Macadam	.10 –.35

When the road surfaces are dry, any disturbance of them naturally raises the dust to some extent. With the slow-moving farm wagon it is inappreciable, but with the high-bodied and narrow steel-tired buggy, moving up to, say, 8 or 10 miles an hour, the bulk of the dust is caused by the hoofs of the horses, as the height of the body of the wagon as well as its slow speed is not favorable to the formation of eddy currents that would tend to keep the dust in the air, so that unless a large number of vehicles passed in succession, or were driven at an unusual rate of speed, the dust would not seriously inconvenience any one. In some experiments made under the direction of Mr. L. W. Page, of the Office of Public Roads, assisted by the Engineers of the A. L. A. M., it was shown that a single horse and buggy

traveling at 10 miles per hour raised dust about 8 feet, and at 15 miles per hour about 15 feet, or about the same dust that would be raised by a motor car going three times as fast.

We have been speaking heretofore of macadamized or broken-stone roads. Now, however, when we consider the ordinary dirt road, the surface of which in dry weather may be several inches deep in dust which is so fine that when disturbed it hangs in the air for a considerable length of time, adding to this a climate where for 9 months out of 12 the sun shines continuously, we have the conditions in lower California that brought about the first serious attempts to alleviate this nuisance. In the large cities and suburbs, sprinkling with water had been tried, and also sea water, the salts of which are deliquescent and tend to retain moisture in the road surface, but they have an injurious effect on horses' hoofs and on the boots of pedestrians.

In about 1894 a short stretch of road in Los Angeles County was sprinkled with the heavy crude oil that is found there, with beneficial results as far as laying the dust was concerned, but with many drawbacks that resulted from the experimental character of the work, such as uneven distribution of the oil, which formed puddles that destroyed the varnish on carriages and splashed on passers-by. The subject lay more or less dormant until 1898, when interest was renewed in it, and methods were adopted which resulted in overcoming the former difficulties. The subject was also attracting considerable attention in France, where the extensive use of automobiles, especially at the famous watering places along the Riviera, had defied the best efforts of sprinkling. Beyond the discomfort produced by the dust, the hygienic effects were discussed by a number of Continental physicians, among them Drs. Schottelius and Gughelminette, who, in 1901, made an extensive study on the effects of dust in spreading disease, and recommended that strenuous efforts be made to abate it. That the increasing use of the automobile was responsible for this awakening in interest is undoubted, so we will briefly discuss its development with reference to this subject.

The first steam road wagon was invented by Cugnor about 1765–1769, but the real start in the industry came in 1886, when Gottlieb Daimler succeeded in interesting Panhard and Levassor, a wealthy firm of carriage builders, in a four-cycle motor. Daimler's first patent was issued in 1887, but a motor cycle was

patented in 1885, and the first Benz patents for a two-cycle belt drive machine was issued in 1886. The first Panhard car was exhibited at the Universal Exposition in 1889. In America there were a great many early experimenters, among them Austin, Ripley, Duryea, Morris & Salom, Hayes and Apperson, and Maxim, and the first public competition was organized by the *Chicago Times Herald* in 1895 for a road race from Chicago to Waukegan. There were 84 entries; seven started and only one car finished, the Duryea. The development of the machine may be shown by the following table of the wheel base, power and speed developed by the winners of the Grand-Prix or the important race if this was not run.

DEVELOPMENT OF THE AUTOMOBILE.

Year.	Wheel Base.	Weight.	Power.	Speed.
	Inches.	Pounds.	H. P.	Miles per hour.
1894.....	51	2030	3.8	12.6
1895.....	...	.....	.....	14.5
1896.....	67	4080	6.0	15.1
1898.....	...	.....	.....	26.8
1899.....	79	2600	16.0	29.0
1900.....	...	.....	.....	38.0
1901.....	92	2204	40.0	43.0
1902.....	...	Restricted	.....	54.3
1903.....	...	.....	.....	56.8
1904.....	102	Restricted	80.0	61.7
1905.....	...	.....	.....	61.8
1906.....	114	Restricted	106.0	62.7
1907.....	...	.....	.....	70.6
1908.....	122	Restricted	120.0	74.3

While these speeds were, of course, only attained by specially constructed machines, the average touring machine developed about one-half of the racing speed, while its weight ran frequently very much in excess of the racing weights which are for the stripped machines. By 1901, then, we would have touring machines averaging 20 miles per hour, and this same year we find a discussion of the possibility of their effect on the Macadam roads at a meeting of the British Association.

With the now rapidly increasing speed the dust nuisance was enormously increased, and the question of possible deterioration of the roads assumed more importance. During 1903 complaints began to come in, and in 1904 the discussion was very general

in the technical press, but many road engineers as yet failed to notice any marked deterioration until 1905, when every one connected with the maintenance of broken-stone roads found that they were rapidly ravelling and disintegrating.

This resulted in the appointment in 1906 of a Royal Commission in Great Britain to investigate the matter, and a general warning was sounded at the meetings of the various scientific societies, where the subject was discussed of the failure of the existing methods of road construction to withstand the high-speed motor traffic.

FIG. 6.

Ten miles per hour.

The first appreciable effect of the passage of a rapidly moving motor, is the dense clouds of dust that appear to envelop the rear of the machine. On roads that are in very good condition with but little surface dust, we can study the problem more easily, and from some photographs made by Mr. Logan Page, Director of the Office of Public Roads, we see how the dust is increased as the speed rises. Up to 20 miles per hour it is not important on a good road, but above this it increases rapidly.

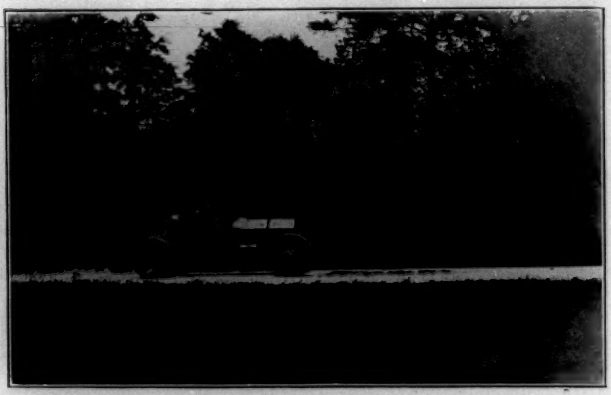
At the tests formerly mentioned in connection with the dust due to carriages, a number of experiments were also carried out with motor cars of different makes. The road had been

given a thin layer of dust, and the following average observations were made with the eye as to the height of dust raised by the machines at increasing speeds:

Miles per hr.....	10	20	30	40	50	60
Height of dust.....	6 in.	2.5 ft.	5 ft.	9 ft.	12.5 ft.	22.5 ft.

On examining closely the tracks made by a rapidly moving machine, we see that for a space 2 to 4 inches wide the road surface appears perfectly clean and free from dust, the heavier particles of which are spread in little ridges on each side of the track. Now from our notes on the dust nuisance, we see that

FIG. 7.



Twenty miles per hour

the theory of the broken-stone road requires the presence of this cementing bond of road dust to hold the stones of the wearing course in position to withstand a vertical load, as this is the only direction that a load can come on a road from ordinary horse-drawn traffic, as in this case the wheels serve only as rolling supports for the load. Now, on the other hand, when we have an automobile, the driving wheels present in addition to this function, that of delivering to the road the couple produced by the motor, and this materially changes the direction of the strain produced at the area of contact of the tire tread and the road.

This action between the tires and the road has been the subject of considerable discussion, and a number of theories have been advanced to account for the action of the motor tires in sweeping the surface dust from the road. The earlier idea was that this was caused by the suction produced on the road surface when the rear of the tire suddenly leaves the road. Mr. Page, from his photographs, showed, however, that this would only account for but a fraction of the effect, as his photographs clearly showed that while there would be considerable dust from

FIG. 8.

Forty miles per hour.

the rear wheels, yet the front wheels were practically free from it. Another theory attributed it to the longitudinal stretching of the rubber tread under the influence of the tangential force exerted by the rim. While all of these causes may contribute to the general effect, it is undoubtedly due principally to the shearing strain put on the upper surface of the road bed by the horizontal component of the driving couple of the motor exerted at the tire tread.

This subject has been discussed by M. Girardanet in *Le Genie Civil* for August, 1908, and by M. Mahieu, in a paper presented at the First International Road Congress in Paris last year.

Mr. Mahieu, who discusses the subject more broadly, has taken up the question of the value of the horizontal component of the stress on the road surface, and has given a number of formulæ for its envaluation. He shows that its value cannot exceed $T = Nf$ = maximum or limiting value where N = weight on a driving wheel, f = coeff. of friction; otherwise the wheel would slip, and that in general it will have a value

$$T = \left(\frac{P}{2} - N\right) f_1 + \frac{Pa}{2g} + \frac{A}{2} \pm \frac{Pi}{2}$$

Where
T = horizontal component.
P = weight of machine.
N = reaction normal to road surface of a driving wheel.
f_1 = coeff. of traction (varies from .025 in a Macadam road to .02 on a paved street).
a = acceleration of the machine.
g = acceleration due to gravity.
A = resistance due to air, this assumed to be equal to $A = k.s.S$, where K = coeff. = .088; s = vertical section of machine; S = speed meters per second.

This is assuming a level road, and the expression $\pm \frac{Pi}{2}$ is the change due to an ascending or descending grade.

To this must also be added on curves the terms $\frac{Pv^2}{gr}$

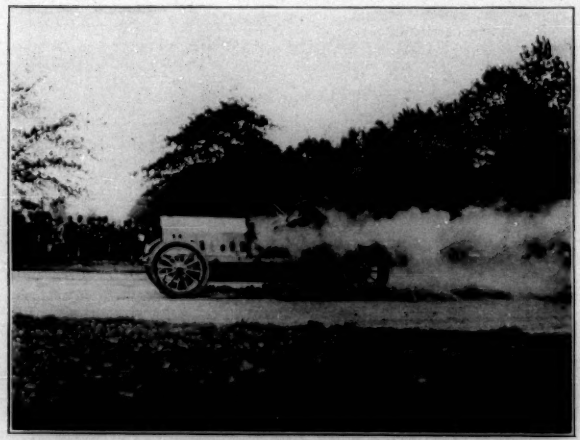
Where v = speed.
r = radius of the curve.

The first term in this expression, is on a level road at a uniform rate of speed the important factor. The second terms are important when starting—or in increasing the speed at any time, particularly when approaching and ascending a hill. The third term becomes important with any machine at high speed, and with limousine bodies having a large vertical section. Furthermore, in case of depressions there is a further momentary increment equal to $d.P.h$. Where d is the fraction of the weight, P on a driving wheel, and h = depth of the depression. This term is in a vertical direction, and it causes the horizontal component to take a slight angle to the surface, thus exercising a more distinctive lifting action, and explaining why a rough road is more quickly stripped than a smooth one. It must be remembered that in no case can the sum of these terms exceed Nf. They also discuss the question of "skidding," and show that a certain speed as relating to the coeff. of friction is required to produce it.

In general $f > .1019 \cdot \frac{v^2}{r}$

serves to connect these quantities on curves. The usual values of f with pneumatic tires are .35 on paved streets and .6 on Macadam roads. They show that the value of the anti-skidding devices in general use (rivet-studded bands) is due to the concentration of the weight on the smaller area of the rivet heads as against the larger area of a plain tread. They give the result of one experiment, where the pressure per square inch of contact

FIG. 9.



Eighty-five miles per hour.

with a plain tread tire was 30.6 pounds per square inch, while an anti-skid tire it was 145.5 pounds per square inch of the rivet head.

It is this greatly increased pressure which causes the rivet heads to penetrate the surface of the road, even with asphalt, that enables the device to accomplish its work, and they call attention to the fact that stringent regulations should be enforced limiting these devices to flat, circular plates at least .4 inch in diameter and not over .12 of an inch in height, and absolutely free from any sharp or cutting edges.

The severe grinding action due to sudden application of the brakes is gone into, and a formula is given showing the relation between the speed and the distance that a machine will travel with locked wheels. It is

$$\left(pf+Kp\right)e=\frac{P}{2g}\cdot v^2$$

Where p = weight on the breaking wheel.
f = coeff. of friction.
K = coeff. = .02.
e = distance traveled after locking wheels.
P = weight of machine.
v = speed.
g = acceleration due to gravity.

In this case the maximum value of T is obtained, *i.e.* $= N F$, and explains the phenomena noted on any roads, where the machines must stop quickly at cross-roads and turns, where the road surface is very badly worn.

In general, they show that this shearing effect is much greater than has been assumed, and that it has been experimentally proven that it must frequently attain its maximum value, by the fact that the experiments by Mr. D. Mackensie have shown that the driving wheels of a motor car travel considerably further than the front or carrying wheels.

They consider that there should be an equilibrium between the possible torque at the tire tread and the weight of the machine, or, in other words, the weight per brake horse-power should be increased rather than decreased until the motor could not slip the wheels. Under these conditions, they seem to advocate properly constructed anti-skidding devices to insure that this action should not take place under unusual conditions. In the tests previously described, the use of chains at 20 and 40 miles per hour perceptibly reduced the dust as compared with smooth tires. We have usually assumed that anti-skidding devices were distinctly disadvantageous to the road surface, and under the present ratio of engine power to weight this is undoubtedly true, as they may act as veritable grind-stones on the road surface; yet given a greater weight per horse-power as above, they may yet serve a useful purpose in preventing the development of the maximum value of T.

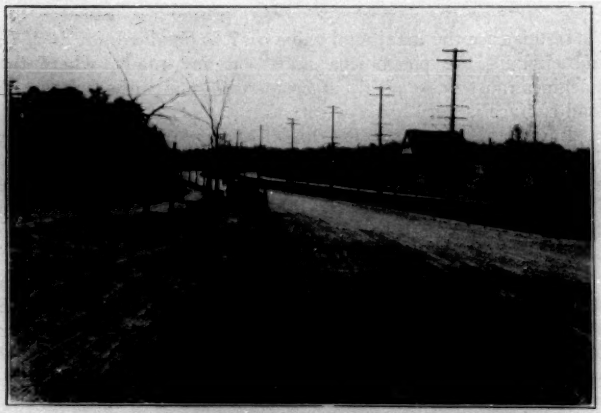
We feel that the above represents in general our present knowledge as to the causes which move the surface particles of

the road and separate them from the matrix of the road when they are blown about and scattered about by the strong eddy currents set up by the compression of the mass of air in front of the machine by its rapid passage, and the rapid inrush of air from all sides of the car to fill the partial vacuum thus created.

Granted that we do sweep the dust from the road, what effect is produced?

When the cementing bond is removed from the stones forming the wearing surface of a road, it immediately becomes

FIG. 10.



Road wear due to automobiles.

porous and allows the infiltration of any surface moisture, carrying with it the detritus of the road surface. This foreign matter has no bonding value, and acts indeed as a lubricant, permitting a movement between neighboring stone particles under the action of the vertical and horizontal stresses imposed upon them. This results in a crushing action and a loosening of the wearing surface in its matrix. When this occurs, the horizontal stress tears the stone from its bed and scatters it on the roadside. The road is now said to be ravelling, and once started it proceeds rapidly, until the whole wearing surface has been torn from

the sub-base and scattered on the road, thus exposing the No. 2 stone. As this course was never intended to do anything but transmit the vertical surface load to the foundations, and is not bonded, it is rapidly disintegrated. Some photographs taken by Mr. C. W. Ross, at Newton, Mass., show that in places nearly 6 inches of the road surface had been cut away and scattered to the gutters. On each side of important cross-roads in our park systems, where automobiles have to stop and start while waiting for their turn, the action is very noticeable, and also at the foot of hills. On curves, as we have shown above, this action is accentuated, and it results in carrying the crown bodily over to the outer edge of the road. Some interesting observations have been made on the roads in France and Germany before and after some of the notable road races which have confirmed these views.

M. Mahieu, in reporting the work of the sub-committee that investigated the roads at Hombourg, Lisieux and Dieppe, summarizes the effect of high speed motor traffic, as follows:

1. It sweeps away the cementing surface material that holds the stones of the wearing surface together, and prevents them from crushing one another.

2. It tears these little stones from their sockets and throws them on the sides of the road.

With reference to this latter point, it is interesting to note that during the Grand-Prix held in 1906, three machines had to withdraw from the race by having their radiators smashed by stones, torn from the road surface and hurled into them by the rear wheels of the preceding machine.

As we have seen the disastrous effects produced on Macadam roads by high-speed motor traffic, it is not strange that during the years 1907–1908 there was a great deal written on this subject, and the feeling of some of the leading road engineers and highway commissioners may well be quoted as showing that the enormous increase in the cost of maintenance rendered necessary concerted action on the part of all road engineers to save the thousands of miles of broken stone road subjected to motor traffic from ravelling and eventual disintegration.

The following quotations will show the drift of this opinion:

"Experience has proved that the broad pneumatic tires of heavy motor cars at high speed draw out the small particles which bind the material of a macadamized road. . . . Motors

have come to stay, and the road builders mean to make the roads fit to carry them." Proc. of I. C. E. (Great Britain), September, 1906.

"In recent years perhaps the most important, and certainly the most difficult problem which has engaged the attention of highway engineers, is the prevention of dust. . . . The problem has now, however, assumed a more serious aspect. The existence of our Macadam roads depends upon the retention of the road dust formed by the wearing surface. But the action of rubber-tired motor cars moving at high speed soon strips the Macadam road of all fine material, the result being that the road soon disintegates.

"This is a subject which should engage the earnest attention of the National Government at once." 1907 Report, Office of Public Roads, Mr. Logan W. Page.

"Perhaps the most important discovery of the year is the extraordinary destructive effects upon stone roads of the large number of rapidly moving automobiles. . . . The commission is satisfied that a material change in the methods of maintaining stone roads must be made. While old methods have proved satisfactory in the past, they fail under the present usage." 1907 Report of Massachusetts Highway Commission.

While there are two phases to this question of road treatment, *i.e.*, the elimination of the dust nuisance and the preservation of the roads, yet with broken-stone roads these two are coincident to a great extent, and may be considered together. In other words, if we can prevent the formation of dust and thus preserve the cementing rock binder in the wearing surface to a very considerable extent we will preserve the road from deterioration. On the other hand, we must remember that even though we present a wearing surface which shall be proof against the destructive effect of high-speed motor traffic, we only eliminate the dust coming under the first heading, *i.e.*, preventable dust, so that we would still have the dust due to the traffic and surroundings to contend with.

There are then four general methods to approach this problem.

1. We may, by suitably treating the road surface, *i.e.*, by moistening or tarring, prevent the dust rising.

2. By incorporating in the body of the present broken stone

road binding and bonding materials, so that the road surface should resist the shearing action of the driving wheels, such as tar Macadam.

3. By making a homogeneous solid surface that is unaffected by the traffic, such as cement.

4. By the use of hard blocks or setts that are proof against the action of the traffic, such as Klempflaster. We will have then the following eight methods that are in use at present, and which we proceed to consider more in detail as representing the efforts that are being made at present to hold the dust nuisance in check and to preserve our roads. (*a*) Sprinkling with water. (*b*) Sprinkling with solutions of hydroscopic salts. (*c*) Sprinkling with emulsions of an oily or bituminous nature. (*d*) Surface coating with oils. (*e*) Surface coating with tars. (*f*) Incorporating oils or bitumens in the road material in making the road. (*g*) Building roads with cement surfaces. (*h*) Building surfaces of small blocks or setts.

While the use of water sprinkling has been almost the universal method for controlling the dust on broken stone roads, it has many disadvantages.

In the first place, it is only applicable to cities, parks, and suburbs, where there is an ample water supply at the roadside. The action of the water is of very short duration, depending on the humidity, temperature, and velocity of wind. This necessitates putting on a greater quantity of water than would otherwise be desirable in order to secure a more lasting effect. So that immediately after the application the surface of the road is softened and becomes muddy; in this condition the action of the motor traffic is particularly destructive. This mud dries out after 20 to 30 minutes, and for from 1 to 3 hours, depending on the atmospheric conditions, the road will be free from both mud and dust. However, as the evaporation continues, the surface again becomes dry and dusty, when the operation must be repeated.

The sprinkling given the road is usually more adapted to the money allotted than to the requirements of the road. In many cities they do not commence to sprinkle before June, and stop at the end of September. Thus, the roads are unprotected from the high winds of the spring and fall, that do a great deal of damage to the surface, as it is then more or less loosened by the

winter frosts or the usually more intense traffic of the summer months. In these places two applications a day, one about ten in the morning and the other at three in the afternoon, are used, thus giving a fairly dustless road through 6–8 of the busiest hours of the day, or about half of our usual living day.

In many of our parks, however, where more money is available, especially in Boston and the vicinity, where they sprinkle throughout the year whenever the dust flies and the thermometer is above 34° F., this results in a sprinkling season of over 200 days, and requires on some days as high as six trips of the cart.

This excessive amount of surface moisture cannot fail to have a destructive effect on the bonding value of the road metal, as it is an intensified action of the usual atmospheric agencies that are credited with about 30 per cent. of the annual deterioration, the action of the horses' hoofs 45 per cent., and the wheels 25 per cent., for ordinary light-tired vehicles.

Under any conditions, unless night sprinkling were resorted to, we could only expect to keep the roads dustless by sprinkling about 12 hours out of the 24, so that watering may be dismissed as of but little value at the present time.

USE OF HYDROSCOPIC SALTS.

The rapid evaporation of water from the surface of the road, and its fugitive value as a dust layer, has led to attempts to retain the moisture in the road by the use of deliquescent or hydroscopic salts which would abstract moisture from the air. The use of sea water was probably the first attempt to make use of this principle, but its hydroscopic action is quite feeble, and the resulting salts had a very destructive and corrosive action on the hoofs of horses, the varnish of carriages, pedestrians' shoes, and on all metal surfaces with which they might come into contact, so that while spasmodic attempts have been made to utilize it they have all been abandoned. In order to find a neutral substance that would have the desired characteristics, experiments were made as early as 1828 with calcium chloride, which has since been quite extensively used for this purpose.

Several patented preparations have lately come on the market, such as Aconia, a secret compound; Lyminite, a mixture made by fusing $NaNO_3$, NaCl and CaO, and dissolving in water; Panscale, the residue from brine evaporators, and Fitzsimmon's Patent Dust Layer, a sodium silicate. These patented prepara-

tions seem to be no more efficient than the calcium chloride, and are considerably more expensive. The general method is to apply at the beginning of the season two strong coatings, about a week apart, using about .25 pounds of chloride per square yard, and then continuing with weaker solutions of about $^1/_{10}$ of a pound per square yard at intervals of 3 to 5 weeks, as the atmospheric conditions require. In England, the practice seems to tend toward the use of more salt with fewer applications, using up to 3 per season. They usually estimate that sprinkling with plain water is required from 1 to 2 times per week between the salt applications. It is necessary, however, after very hard rains to immediately apply the salt solution again, as owing to its being very soluble it is all washed from the road. Although the calcium chloride has no specific bonding value, yet its use is immediately apparent on the road surface. The surface becomes darker in color from the moisture and iron in the salts, and appears of a very close and compact texture, due to the surface retaining all dust and thus sealing the voids. Ravelling is prevented to a considerable extent, and what little dust may be lifted seems to be very heavy, so that it drops back almost immediately, so that in general we may say that its use is beneficial to the road.

The above observations apply to roads that do not support a very heavy traffic, as under the latter conditions it does not seem as effective. Owing to the fact that it is practically colorless, odorless, and of a neutral reaction, it is particularly adapted for quiet residential streets, and for promenades where foot traffic is important.

The Calcite Process Co., of Boston, have developed a method for using this material that seems very effective and economical, and they undertake to render streets and roads dustless by contract for a fixed rate per square yard per season.

EMULSIONS.

The use of emulsions of oil and tar should properly be considered after treating of these agents as surface treatments, as emulsions were designed to obviate several disadvantages from their use, such as the necessity of preparing the road surface, heating the components, labor of spreading and the necessity of closing the road to travel during the application. Yet their use and application is so closely related to the former paragraph on

hydroscopic salts that it was thought well to treat of them together. They were first developed about 1903 and 1904 in France and Germany, and the market was soon flooded with patented preparations with fantastic names, all claiming marvellous dust laying properties. In general, they are an emulsion of tar or tar oils, asphaltic petroleum, asphalt or, in some cases, of waste oily products made with soda or ammonia, and are expected to be diluted with water and applied to a road surface without previous treatment, from an ordinary sprinkling cart. The following is a list of the more important, and what information we have concerning them.

LIST OF EMULSIONS.

APOKONIA. Product of heating heavy residual oil with phenols.
APULVITE. Powdered asphalt with emulsinifier.
BASILITE.
BOUHAROL PROCESS. Coal tar and soap.
COOK'S EMULSION. This is a general process of emulsifying asphaltic base oils with a soap solution. A formula which is widely used is as follows: 8 bbls. of asphalt base oil, emulsified with 18 pounds cotton-seed oil soap; made up to 600 gals. Mixed for use with three parts of water.
CREMPOID R. Glue, bichromate of potash, oil, tar.
CREMPOID D. Glue, bichromate of potash, oil, no tar.
DUSTABATO SYSTEM.
DUSTOLINE. Thin yellow oil, no body.
DUSTROYD. Wool grease emulsified.
ERMENITE. Cotton-seed oil treated with H_2SO_4 at an elevated temperature, washed, mixed with 4 parts by weight of tar, emulsified with hot NaOH, diluted with water to contain 20 per cent. of tar. For use this stock solution is diluted with 4 parts of water.
EMULSIFIX. Tar mechanically emulsified with water.
HAHNITE. Carbolic acid and oil emulsifying tar and asphalt at 150° F.
INJECTOLINE. A non-freezing oil.
ODOCREOL. A tar oil.
NEWSTRANS.
POSSIDERITE.
POSISSIEROL.
PULVICIDE. 50 gal. creosote oil, 112 pounds pitch, 252 pounds resin, melted and mixed with solution of 28 pounds NaOH in 18 gal. of water. Diluted with ten times its bulk of water for sprinkling. Lasts about ten days.
PULVIVORE. Shale oil from Autun, France.
PULVERENTO. Tar oil, mineral oil, carbolic acid, emulsified with ammonia.
RAPIDITE. Powdered asphalt mixed with emulsifier.
RIPLEY'S COMP.
SANDISIZE. Grease from wool scouring emulsified with potash, patented U. S. 813,389, Feb. 20, '06.
SIMPLICITE. Costs 4 c. a pound.
SULPHITE PITCH. This is a by-product in the manufacture of sulphite cellulose. It is soluble *per se*, in water and is said to have given very good results. This appears to be the most satisfactory article yet proposed for use with water.
TERRACOLIA. Ammonia emulsion of oil with coal tar.
WESTRUMITE. Emulsion of tar and mineral oil with ammonia.
ZIBELLITE. Costs 2.5 c. a pound.

While it is true that by their use the dust can be laid for a short time at a small labor cost, yet in the aggregate for a season, it amounts to quite a high figure. This is theoretically as it should be, as the mixture of water with the oily mixture to some extent defeats the very object that we wish to obtain, *i.e.*, the securing of a well-bound waterproof surface. Again, the alkalies used in forming the emulsion destroy, to some extent, the bonding power of the oils used, and, furthermore, in many of the preparations the oils are not properly suited to the work in hand.

The same general objections apply to the use of emulsions as apply to hydroscopic salts. They do lay the dust if applied in sufficient quantity, but they have little, if any, permanent binding effect on the road surface. They are almost entirely removed by a heavy rain, as through their application with water they cannot penetrate below the surface of the road. In many cases, particularly with the asphaltic base oils, they have a very disagreeable odor for several days after their application. Again, a number of the patented emulsions are made with an excess of alkali as an emulsifier, and their use occasions considerable annoyance to the eye from the particles thrown by the wheels of motor cars passing shortly after they have been applied.

SURFACE COATING WITH OILS.

Coming now to a consideration of the use of surface dressing of oils, we find the first really successful methods of controlling the road dust. The inception of this treatment came from the climatic and physical condition existing in countries having long, hot, rainless seasons, but their use has been extended to other districts with varying degrees of success. The following table gives an idea of the chronological development of its use:

DEVELOPMENT OF USE OF OIL AS SURFACE TREATMENT.

1894. First tried in Santa Barbara, Cal.

1898. Revived in Los Angeles and San Bernardino, Cal., using the heavy asphalt oil, and in Oran, Algeria, using oil of aloes.

1899. A Texas asphalt oil was used successfully in Fort Worth, Texas; tried in Boston Parks, and abandoned on account of odor.

1901. A paraffin base oil was used for oiling a railroad roadbed in Long Island.

1902. The same class of oil was used in some sections of the Penna. R. R. Texas asphalt oil was used successfully on the shell roads at Galveston, Texas. Experiments at Marion, Ind., on a Macadam road with a crude paraffin base oil were not successful, and at Liverpool, Eng., Denver, Col., reported dust-laying properties excellent.

1903. Paraffin base oils were unsuccessful at the Rock Island Arsenal. Experiments with "Masut," a residue from the Baku refineries, were made in France; not very successful.
1904. The use of the asphaltic base oils from Kentucky was commenced in Fayette Co., generally successful, and at Washington with indifferent results.
1905. Government experiments with Texas oil and residues were successful.

Reviewing these results has shown two things—first, that paraffin base oils are not suitable, and second, that even the asphalt base oils succeed best in dry, warm climates.

The paraffin base oils have no binding properties, and in fact are even more than useless, as on Macadam roads they serve as a lubricant between the stones in the wearing course, and seem to hasten their destruction by grinding. Again, they evaporate more or less rapidly and soon entirely disappear from the road, and, furthermore, they are not oxidized as the asphalt base oils are, into a tough material resembling the national bitumens. While all the oils tend to "churn" more or less (that is, tend to form a black, slimy mud) under the action of the frost, traffic, and excess moisture from snow, the paraffin base oils are the worst offenders.

The climatic influences are exceedingly important factors in any question of road treatment, and have frequently not received the attention that they deserve. This is especially noticeable in the use of oil. Originated in the hot, dry climate of California, where for 8 or 9 months there is no rain and frost is unknown, and where the road surface may be secured perfectly dry, warm, and in an ideal condition to receive and absorb the oil, it has succeeded wonderfully well, but this success has led to its use under the trying condition of our Eastern climate where mild weather, snow and frost rapidly alternate, and add to this an annual rainfall of from 35 to 60 inches, so that their indifferent success under these trying conditions is not surprising.

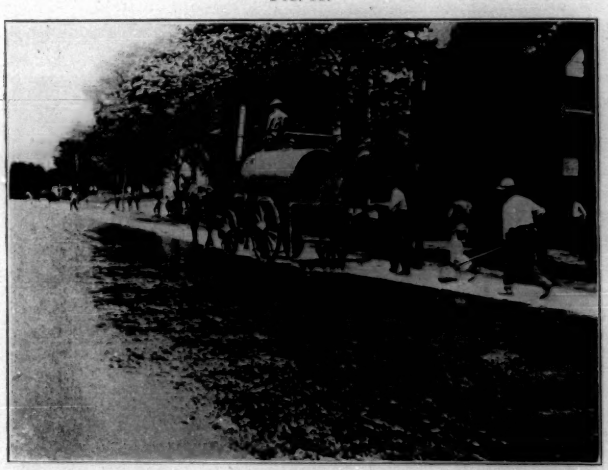
There has been a great deal of experiment and practical work done on the application of oils to road surfaces, and the conditions essential to success seem pretty well understood, so that it seems unnecessary to describe the earlier experimental methods. There are still two points that seem to be in dispute, *i.e.*, whether to sweep the road or not, and whether it is best to heat the oil or apply it cold.

These points may usually be decided by considering the conditions under which the process is applied; but frequently the

exponent of one system or the other will endeavor to point out general conclusions from his own restricted conditions and experiments.

The general method seems to be as follows: In very dry climates and especially on gravel roads, it seems unnecessary to sweep the road. In the Eastern States and on Macadam roads this seems essential, but it can be done sufficiently well with a horse sweeper.

FIG. 11.



Oiling a road.

The oil should then be applied from some form of sprinkler provided with control over the delivery, such as the White Road Oiling Machine, which was developed in California for this purpose.

In California or the Southern States, or in the Eastern States during hot summer weather, heating does not seem essential, especially with oils containing not over 25 to 40 per cent. of asphalt, but for general use, in the East especially, with the heavier oils, the heated oil can be more easily and economically handled and applied than the cold oil, and seems to give slightly better results, particularly on Macadam roads.

Brooming the oil after spreading is generally determined by the way the road surface takes the oil, but at least one or two men should follow the sprinkler when using heavy oil, especially if cold or the road surface uneven, to brush out all puddles and push any excess into the gutter.

Sanding.—This is exceedingly important, as the value of many oils seems to lie chiefly in the formation of a hard coating of oil-saturated sand that fills all the surface voids and presents a smooth, resilient surface to the traffic.

FIG. 12.

Spreading oil after sprinkling

In many cases it is found that the surface application of oil, while it only penetrates the original road about ¼ to ½ of an inch (the latter is exceptional) tends to loosen and disintegrate the original cementing bond of rock powder, an action similar, no doubt, to its action on cement concrete, so that without a sand-wearing surface the road would soon go to pieces.

It is now generally felt that under these conditions the sand should be carefully chosen and applied until the oil fails to come to the surface. A slight excess seems, in the opinion of a

number of road engineers, particularly about Boston, to be even desirable.

In general, oiling seems to succeed better on gravel than on Macadam roads. There are several reasons why this is so. The gravel road is more porous and allows a greater penetration than in the compact and almost impervious wearing surface of a broken stone road. The action of the oil in loosening the bond in the wearing surface of stone roads has already been noted, and is, of course, a factor against its successful use. In the gravel road the particles especially, are subject to more or less motion, from the stresses imposed by the traffic, that owing to the regularity and smoothness of their surface is not destructive, while in the broken stone road such action is to be prevented as the surface quickly disintegrates under it. This then requires that a surface binder should have such a character that would permit this motion without detriment to its wearing qualities, or, in other words, it should be of a rubbery consistency. This is well exemplified in the base of the California oils high in asphalt.

The proper quantity of oil per square yard is dependent upon the ability of the road surface for absorbing it. An excess is very undesirable as it requires too much sand to prevent it damaging traffic, and if too thick this sanded skin peels and leaves a very poor surface. In general, gravel surfaces will absorb more oil than Macadam, depending, of course, on the quality of oil used, and whether cold or hot. The usual practice seems to be from .2 to .3 gallons on Macadam, .3 to .4 gallons on gravel, and .4 to .7 gallons on earth roads.

Almost any asphaltic or semi-asphaltic base oil seems to serve for surface treatment, but they should contain from 25 to 40 per cent. of D grade asphalt, and be reasonably free from water and foreign matter.

Oiling seems to succeed best on gravel roads in hot, dry climates. It requires for its best results even distribution of a fairly clean road surface. It is easily applied, and gives a dustless surface, but frequently gives a good deal of trouble if an excess is used, and in winter in the Eastern States churns to a slimy black mud. There is with some oils considerable nuisance from odor and tracking when first applied. The climatic conditions and character of road surface should be carefully considered before adopting its use.

(To be continued.)

SCRUB PINE FURNISHES WOOD PULP MATERIAL.

THE long neglected and despised scrub or Jersey pine, growing on the abandoned farms and cut-over lands of the East, seems destined at last to have reached its rightful place as a material of value, according to the results obtained through recent pulp and paper making tests at the United States Forest Service laboratories in Washington.

While there is a considerable amount of this wood standing as timber, it has heretofore been used only in a very desultory fashion, and then mostly as fuel. About 500,000 acres, or 20 per cent. of the wooded area of Maryland, and about 130,000 acres, or 10 per cent. of that of Virginia, is covered with fairly dense stands, while the broad range of the tree extends along the Atlantic seaboard from southern New York to South Carolina, and back over the Appalachians to central Indiana, where its largest specimens are found.

While a number of mills have used scrub pine for the manufacture of soda pulp and ground wood, no plants have ever operated the sulphite process. Scrub pine might have been used to good advantage long ago, but for the fact that it did not seem to the practical paper maker even worthy of trial. By only slight changes of the regular cooking treatment which is ordinarily accorded pulp wood in the sulphite process, however, it has now yielded a pulp product which has been favorably commented upon by numerous members of the paper trade as a substitute for spruce sulphite in the manufacture of newspaper.

When a forest of scrub pine is matured, a fully stocked stand will yield thirty to forty cords per acre, when economically harvested according to the practical forestry methods. At the present time there is practically no general use for the timber, outside of fuel, although a coarse lumber is made of it and it is sometimes used for fencing. An evidence of the low esteem in which this pine is held is the price which the Maryland wood brings when delivered—$5.75 per cord. The wood itself is of a light yellow color, with a white sap wood. It is light in weight, is brittle, and coarse-grained. While it is fairly durable in contact with the weather, its weak structural properties offset any advantage this might give.

One advantage for paper making which scrub pine is said to have, is the fact that there is considerably less loss in barking it than with ordinary spruce. The logs are, in general, regular and not difficult to handle. The wood yields quite easily to a sulphite treatment when using an acid cooking liquor slightly stronger than the ordinary mill strength. In treatment the wood requires from eight to eleven hours, while the maximum steam pressure has not been over sixty pounds temperature (150 degrees centigrade) and in some cases it was but 54 pounds. The unbleached pulp in these experiments is of a light grayish or brownish color, not unlike that from spruce, of course depending upon the cooking conditions, which can be controlled to suit the manufacturer.

The fibre is strong and durable, and is about the same size as that of spruce, being possibly a trifle broader. The yields obtained by the Forest Service are about the same as are obtained from the woods now in general paper making use. The amount of screenings is very low. Scrub pine presents no serious disadvantages in regard to bleaching. A good white color is readily brought about. While some of the cooks require more bleach than is ordinarily practical or economical, yet by cooking properly the amount of bleach required has been brought down to 360 pounds or 35 per cent. bleach per ton of pulp. By slightly changing the conditions of treatment, it is believed that still lower percentages may be employed while the color produced remains the best white.

Practical paper makers who have seen this product are almost unanimous in claiming it to be a strong, long-fibred, and hard-wearing pulp, which seems especially desirable for making bag, news, and wrapping papers.

Several even went so far as to say that it would make fine bank or ledger papers when properly handled, and that this wood gave one of the best fibres which has been prepared from pine wood.

CONSERVATION OF THE METALS.

RAPID EXHAUSTION OF AVAILABLE SUPPLY.

At the recent meetings of the National Conservation Commission and at the Washington conference of the Governors and the various State Conservation Commissions the fact was strongly emphasized that the visible or known supply of certain of the most important metals of the United States is being very rapidly exhausted. This fact probably need not yet cause concern for the immediate future of the industries dependent on these metals, but the plea for judicious husbanding of these resources must commend itself to all thoughtful persons who are interested in the future welfare of the country.

RE-USE OF METALS.

In this connection economy in the use and recovery or reclamation of metal products often wasted is undoubtedly of much importance, but in order that its importance may be more fully understood stastics on these subjects are desirable. The extent to which old metals are recovered and re-used in the United States has been heretofore more or less a matter of conjecture, particularly outside of the industries immediately concerned. A similar lack of information has existed as to the extent to which economy in the use of metals is practiced by their recovery from skimmings, drosses, by-products, etc. In Europe incomplete statistics of such production of metals are gathered, and for 1907 the United States Geological Survey made a systematic attempt to ascertain the production of copper, lead, zinc, and tin so recovered in this country. To distinguish them from the so-called primary metals, which have been produced directly from ore and have not yet entered consumption, these metals are called secondary.

STATISTICS SHOWING RE-USE OF METALS.

A part of these secondary metals is produced and sold as raw metal, but a very considerable portion is turned out as alloys, such as brasses, bronzes, babbitt, and type metal. The following table gives the results obtained by the canvass of the industry:

PRODUCTION OF SECONDARY METALS IN THE UNITED STATES IN 1907.

	Short tons.	Approximate value.
Secondary copper as raw metal and in alloys	30,240	$11,188,800
Secondary lead	9,990	2,702,788
Recovered lead in alloys	15,508	
Secondary spelter	18,841	
Recovered zinc in alloys	1,417	2,300,444
Secondary tin	93	914,404
Recovered tin in alloys	1,569	
Total		$17,196,436

This table is compiled from reports made by all smelters and refiners of secondary materials with whom it was possible to get into touch. Producers of such metals who have not received the Government requests for their production will contribute to the conservation movement as well as confer a favor by forwarding their names and addresses to the United States Geological Survey, Washington, D. C.

FRANKLIN INSTITUTE

(Stated meeting held Wednesday, May 19, 1909.)

THE PRESENT ASPECTS OF THE PANAMA CANAL FROM THE TOURIST'S POINT OF VIEW.

BY

WILLIAM TATHAM.

THE idea of a canal is almost as old as the discovery of the Isthmus. It is said that in the year 1620 one Diego de Mercado submitted a report on the subject to Philip II, but the King of Spain replied that the will of God was made manifest when he created an isthmus instead of a strait, and it would be impiety for man to attempt to unite the waters of two oceans which God had separated. The project was declared sacrilegious, with the usual penalties, and the matter was dropped.

In the early part of the Nineteenth Century attention was again directed to the Isthmus and various surveys were made by the United States Government and others. Finally, in 1879, Count Ferdinand de Lesseps formed a company and began the work of digging the canal. The original intention of de Lesseps was to make it a sea level canal, but as it was found impossible to complete such a canal within any reasonable time the lock type was adopted. The company finally went into liquidation and a new one was formed which also eventually came to grief for want of funds. It is unnecessary to dwell at length upon the events which led up to the acquisition of the property rights and privileges of the French Canal Company by the United States.

The people of Panama had never been satisfied with their relations with the Bogota Government and had made, from time to time, attempts at separation, some of them resulting in much bloodshed, but none of them successful. The failure of the Hay-Herran Treaty in 1903 resulted in conditions which seemed to give them an opportunity of which they promptly took advan-

tage. The result was that the United States got a concession from the new Panama Republic under the terms of which it was possible to build the canal. It is very doubtful whether the canal could be completed under conditions less liberal than those granted by the Republic of Panama.

THE CANAL.

The Panama Canal is about 51 miles long from deep water on the Atlantic side to deep water on the Pacific side, but as the distance from deep water to the shore line in Limon Bay, in the Caribbean Sea, the Atlantic side, is about 4½ miles and from the shore line to deep water at La Boca, the Pacific side, is about 5 miles, the canal proper, from shore to shore, will be about 41 miles. From Limon Bay to Gatun locks and dam it will be a tide-water canal for 4 miles. The tide at Limon raises about 18 inches. From Gatun to Pedro Miguel, 3½ miles, it will have a summit elevation of 85 feet above the sea. From Pedro Miguel to Miraflores, about 2 miles, it will have a summit elevation of 55 feet, and from Miraflores to La Boca, on the Pacific Side, it will be a tide-water canal. The tide on the Pacific side is from 18 to 22 feet. The bottom width of the canal in its narrowest part, Culebra cut, will be 300 feet, with an indefinite width in the deep waters of the Gatun Lake. On both ends of the canal, from deep water to land, the channels will be 500 to 1,000 feet wide and the cuts in the shallow parts of the lake will be from 500 to 1,000 feet wide. The minimum depth of the canal will be 41 feet.

The total estimated excavations required by the present plans for the lock canal are in round numbers 175,000,000 cubic yards, of which up to March 1, 1909, has been excavated 66,000,000, with an amount yet to be excavated 115,000,000, so that considerably over one-third of the excavation work has been done. It is therefore estimated that, taking into consideration the work on the dam and the concrete in the locks, the canal will be open for traffic by the first of January, 1915.

STEAM-SHOVEL EQUIPMENT.

The excavating is done by means of steam shovels in the dry portions and by dredges in places covered by water. Mules and scrapers are used for stripping in some places. There are

now in use on the Isthmus 101 steam shovels—48 ninety-five-ton, 42 seventy-ton, 10 forty-five-ton, and 1 thirty-eight-ton. The ninety-five-ton shovel holds 5 cubic yards and dumps into flat cars, each car holds 7 shovels, or 35 cubic yards. There are 17 cars in each train. As each car is loaded the train moves slowly on until all the cars are full, and is then hauled to the dump, and unloaded by the Lidgerwood unloader as follows: The flat cars have side boards on one side only and no end boards, and the spaces between the cars are covered with steel plates. The unloader, which is a plow-shaped affair, is drawn from the rear end of the train to the front by means of a steel cable attached to a steam winch on a special car next to the engine. When the plow gets to the flat car next to the winch it is stopped and the car with plow is detached.

To repeat the operation, the train is made up with the car containing the plow attached to the rear end; it is backed up until the winch is under a gallows frame arrangement set over and across the track. The cable is then hooked on to the frame and the train is run forward until the plow is under the frame, the cable taken from the frame and attached to the plow and the train is ready to be unloaded at any convenient place. It is very interesting to watch a train unloading by this method, the plow slowly advancing and pushing earth and rock, in many cases huge bowlders, from the car to the dump.

In excavating by steam shovels, the ground is first loosened, and rocks shattered by means of dynamite.

Besides the cars used in connection with the Lidgerwood unloader there are in use steel dumping cars holding about 30 cubic yards which are unloaded by air pressure from the engine. A whole train may be dumped at one time. The steam shovels work very rapidly. The average time of several cars in the Culebra cut was about one minute and a half. Of course, this does not represent the actual work done in a day of eight hours. There is a good deal of time consumed in moving the shovels, shifting trains, etc. The highest daily record for a single shovel is something over 1,600 cubic yards per day of eight hours.

EMPLOYEES.

In the month of February, 1909, there were on the Isthmus about 41,000 employees on the roll of the Commission and the Panama Railroad Company, of which 5,000 were Americans.

There were actually at work on February 3, 31,071 men; 24,911 for the Commission and 6,160 for the Panama Railroad Company. Of the 24,911 men working for the Commission 4,278 were on the "gold roll," so called, who were paid in United States currency, and 20,633 on the "silver roll" who were paid on the basis of the Panama currency or its equivalent. Those on the gold roll include skilled mechanics, locomotive engineers, machine-drill men, etc., clerks and higher officials. They are for the most part Americans. The silver roll includes the common laborers, who are practically foreigners.

The working day is eight hours. The men begin at 7 A.M.; work until 11 A.M.; take the midday meal, rest until 1 P.M., and work until 5 P.M. They are carried to and from their work by train. The Negro laborers use open cars or the roofs of cars, where they bask in the sun; white men prefer closed cars.

The majority of the laborers employed on the canal are drawn from the West Indies. When we were on the Isthmus there were 52 different nationalities on the pay roll according to the languages spoken by the employees. There were from 5,000 to 6,000 Europeans—mostly Spaniards from the north of Spain—and some Italians; the former constitute by far the best class of laborers on the Isthmus. The Italians are good workmen but rather hard to manage. The Negroes are, like all that class of laborers, poor. We had an illustration of this at the Tivoli Hotel in Panama. A negro was set to work cutting the grass on a plot, an oval, about 175 feet long by 50 feet wide, say 300 square yards. He was supplied with a lawn mower, a scythe, and a rake. He started to work the day we arrived and it took him just a week to complete it. It is true that the grass was thick and heavy, and he spent a good deal of time in meditation and smoking cigarettes.

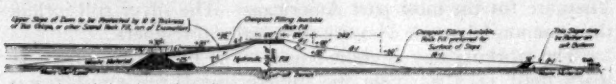
GATUN DAM.

The most striking features of the canal are the Gatun dam and locks, about which so much has been written in the newspapers, and the Culebra cut.

The Gatun dam will impound the waters of the Chagres and the rivers emptying into it between Gatun and Pedro Miguel, forming the Gatun Lake with a surface area of some 165 square miles. The dam is about 8,000 feet long, across the valley of the Chagres. It will be 2,000 feet wide at the base, and 115 feet

high. The crest of the dam is 100 feet wide and 30 feet above the mean water level of the lake. It is an earth dam with a core of puddled clay impervious to water, 700 feet wide at the base and rising to 90 feet. This will be made by hydraulic fill.

About the centre of the valley is a hill rising some 110 feet above sea level. It is here that the spillway of the dam is located. It is of concrete and fitted with sluice gates, so that any amount of surplus water may be allowed to waste. In view



Reproduced from *Engineering News*.

Cross-section of Gatun Dam.

of the vast surface area of the lake, however, it is doubtful if any amount of water will necessarily be wasted.

FOUNDATIONS OF THE DAM.

There has been a great deal said about the foundations of the dam—that it is soft mud, that it is fissured rock and that it is permeable by water, that it has underground water courses,—indeed, were we to listen to the hostile critics it would seem ridiculous to attempt to build any dam whatever at that spot.

In a most admirable report on the Gatun dam investigation, page 127, Report of the Isthmian Canal Commission for 1908, Mr. C. M. Saville, Asst. Engineer, gives the result of exhaustive investigations of the foundation of the dam by test pits and bore holes. The report shows conclusively that the foundation is safe and that a dam can be built which will fulfill all the requirements of the case. It is true that water was found in some of the holes, it is also true that fissured rock was found and that water did appear through some of the cleavage planes. But Mr. Saville's conclusions are in favor of building the dam at that place. He finds:

"First. That suitable material is available and near at hand for the construction of the Gatun dam by hydraulic process.

"Second. That the foundations are suitable for such a structure as the proposed Gatun dam if they are properly treated.

"Third. That it is practically possible to construct a stable and water-tight earth dam at Gatun of the material available.

"Fourth. That the hydraulic method of construction as proposed for this work is feasible if proper conditions are observed."

And that is just what they are going to do.

To quote, in this connection, from a paper entitled "The Isthmian Canal," by Lt. Col. George W. Goethals, U. S. A., Chairman and Chief Engineer Isthmian Canal Commission. Washington, March 16, 1909: "I venture the statement without fear of contradiction, that the site of no public or private work of any kind has received such a thorough and exhaustive examination and investigation as the foundations of the dam and locks at Gatun. There is no longer a doubt concerning the underlying strata; neither the impermeability nor the ability of the foundations to bear the loads that will be brought upon them can be questioned if the data be carefully and impartially examined."

Here we have the word of an eminent engineer who is responsible for the success of the work, whose reputation would be affected by the failure of the dam. By referring to the plan of the dam, you will see the numerous borings made in the foundations which supply the basis for Lt. Col. Goethals' views. Besides this, five test pits were sunk, into one of which Mr. Taft descended when he was last on the Isthmus.

THE LOCKS.

The locks will be built double, of concrete, three in flight; each lock will be 1,000 feet long and 110 feet wide. They will be fitted with double gates. The lift of each lock will be 28 feet 4 inches, making the total for the three 85 feet. The pier dividing the locks is 50 feet wide and will extend 1,000 feet beyond the ends of the locks. Vessels coming into the locks will make fast to this pier and will be put through the locks by electrical machinery. They will not pass the locks under their own steam, so that there will be no danger of their rushing in under full headway and carrying away the gates. There will be an emergency dam which can be used at the upper end of the locks to shut the water off in case of accident.

Leaving the Gatun Dam vessels will steam up the Gatun Lake, 85 feet above the sea level, to the Culebra cut. The Gatun Lake is a very important feature of the canal. On account of the surface area there will be no speed limit for vessels passing

through, and the lake disposes once and forever of the danger of floods in the valley of the Chagres. It will be an agreeable diversion from the monotony of a sea voyage to sail through this inland sea surrounded by mountains clothed with tropical vegetation.

The Culebra cut crosses the Cordillera at a point where the highest elevation is 330 feet above sea level. As the bottom of the cut will be 40 feet above sea level it would make a vertical cut 290 feet at the deepest part. The bottom of the cut is now about 85 feet above the final level.

At Pedro Miguel, pronounced by the Americans Peter Magill, there is one lock with 30 feet lift, thence to Miraflores, about one mile and a half, where there are two locks in flight with a total lift of 55 feet. All of these locks are double. At Miraflores there is a lake of about 2 square miles surface area formed by the locks and a small dam. From here there is a tide-level canal to the Pacific Ocean.

HOUSING AND FEEDING THE EMPLOYEES.

Housing and feeding the large number of employees was a very important question which has been most successfully met. In addition to the old French houses which have been reconstructed, the Commission built over 5,000 houses. They are enclosed in brass wire netting for protection against mosquitoes. There are married and single quarters for whites.

Subsistence is supplied by hotels, European laborers' messes, and the common laborers' kitchens. Commissaries are established at the various towns along the line of the Panama Railroad. They supply the needs of the people at prices about equal to what is charged in the United States. I can personally bear witness to the excellent quality of the food which I got from these hotels.

SANITATION ON THE ISTHMUS.

But the most noteworthy department is that of Sanitation. When the Canal Commission took charge there was a total lack of sanitation on the Isthmus and yellow fever and malaria were very prevalent. In 1905 there was an epidemic of yellow fever and almost a panic among the white employees of the Isthmian Canal Commission. Col. W. C. Gorgas, U. S. A., who has been so successful in fighting yellow fever in Cuba, took charge of

the work and has succeeded in making the Isthmus as healthy as any place in the tropics. It must be remembered that the streets of Colon and Panama were not paved, and there was no water supply and no sewage system in either city. Col. Gorgas took charge and there is now a good water supply available in Colon and Panama and the points along the canal; the streets are paved and a sewage system installed. There has not been an original case of yellow fever on the Isthmus in the last two years and malarial fever is steadily decreasing. There are practically no mosquitoes in the towns in the zone. This result has been obtained by the persistent use of oil where the insects breed, and by keeping the grass and brush-wood cut close in the neighborhood of habitation and along the line of the Panama Railroad.

The work done in the sanitation of the Isthmus has been stupendous and too much credit cannot be awarded to Col. Gorgas and his assistants.

The principal hospitals are situated at Colon and Ancon in Panama and there are sick camps and dispensaries at convenient stations along the line. There is also a sanitorium for convalescents on Taboga Island at Panama.

The death rate in 1908 among the white employees was 15.34 per thousand. About one-third of this death rate was due to accidents and violence. The death rate among the blacks was 19.48 per thousand. The reason for the excess among the blacks was the lack of sanitary precaution among them.

SOCIAL LIFE.

The material wants of the employees being thus provided for, attention is also given to the social side of life on the Isthmus. On the principle that the happier and more contented a man is the better service will he render, amusements are encouraged and athletic sports are fostered. There is a band composed of employees, maintained by the Government, and concerts and dances are given every week alternately at the various stations along the line. Almost every town has its base ball team and they have what one may call inter-city games.

At Ancon there are tennis courts laid out by the Government which are extensively patronized. A feature of life on the Isthmus is the work of the Young Men's Christian Association.

Club houses have been opened at various points where the number of employees is sufficient to warrant their opening. These club houses have libraries, gymnasiums, entertainment halls, etc., and there are frequent open-house receptions and public entertainments. We visited the club house at Culebra and were much pleased with everything we saw. Besides these there are bowling clubs, musical and social clubs along the line and last but not least many women's clubs whose members doubtless discuss everything under the sun from the rearing and management of infants to the election of the President of the United States.

Medals are awarded for two years continuous service on the Isthmus subsequent to 1904, and for each two years additional service a bar will be awarded to be attached to the medal. Only American (or naturalized), citizens are eligible for medals.

The children have not been neglected. In 1908 there were eleven schools for white children and fifteen for black children at places along the line.

The Canal Record, published weekly under the supervision of the Commission, gives a report of progress for each week with details of work accomplished at various points. Also a portion of its space is devoted to social matters and discussions upon various subjects. Thus when we were there a lively controversy was going on as to who was worth more to the community—a married man or a bachelor. The papers and arguments were very creditable and some of the views quite novel.

Under all these conditions we can readily see that a certain amount of enthusiasm and *esprit de corps* have resulted which make this an ideal force, and one has only to observe the bright and earnest faces of the men who are doing the work to feel assured that they are doing their utmost not for pay alone, but that they are the people who are doing the most wonderful engineering work in the history of civilization.

CITY OF PANAMA.

Just a few words on the city of Panama. The city of Panama, the capital of the Republic, was founded in 1672, about a year after the destruction of old Panama by Morgan and his buccaneers. It is to-day a town of some 35,000 inhabitants and in nowise differs from the ordinary Spanish-American town one

finds throughout the West Indies, except that the streets are well paved and that it has an ample supply of good water and an excellent sewage system, which it owes to the American occupation. The streets are clean and well policed. There is a very fine Opera House built, by the way, with part of the money paid by the United States for the concession of the canal zone. The public buildings are creditable. The sea wall on the bay side is fine and forms a promenade for the citizens. There are a few ancient cannon mounted on the sea wall, the carriages being mostly decayed. We could not decipher the inscriptions as the metal was much corroded, but they are doubtless very old.

The most notable object, however, is the ruin of the old Jesuit church of San Domingo, in which is the celebrated flat arch. The span of this arch is 36 feet. There is no burden on the arch, it stands there as it was built. The story goes that the architect failed twice. The third time he uttered a prayer—some say to San Domingo, some say to the Devil,—but in any event he stood under the arch when the supports were taken away for the third time and the arch stood. The church is about 200 years old and the existence of the walls and the arch is a refutation of the reports of frequent earthquakes about which we hear so much. Indeed people, whom we met in Panama, who had been on the Isthmus since 1904 were unable to give us any information about earthquakes in that region. Panama has the distinction of being the first diocese established on the American continent.

Panama has no army and no national debt. As the United States guaranteed the independence of the republic, there is no need for an army and, as they are a slow-going and conservative people, they are unable to see the necessity for a national debt.

LOCK-TYPE CANAL.

There has been a campaign, conducted with much sound and fury, against the lock type of canal and in favor of the sea level type. There has been so much said by the advocates of the sea level system and so much ignorance of existing conditions displayed, and misrepresentation made, that a few words on the subject may not be amiss. It is only fair to say, that before visiting Panama, I shared the prejudice in favor of the sea level type. The advocates of the sea level canal may be divided into

two classes—those who are in favor of a canal without dams and locks, with no provision made for the control of the Chagres and other rivers, trusting to the canal itself to carry away the surplus water when these streams are in flood, and those who would control the Chagres, etc., by means of dams and diversion canals, upon a somewhat similar plan to that originally contemplated by de Lesseps.

The first plan is not worthy of serious consideration. The second plan contemplates a masonry dam at Gamboa 4,500 feet long, 750 feet of which would have to bear a pressure of 170 feet of water during the flood stages of the river. Sluice gates would be arranged to discharge the river into the canal, but there would probably have to be a diversion canal to carry off the surplus water. They make, in their plans, no provision for taking care of the other rivers which would flow into the canal, but there would be at least three or four other dams and a diversion canal on the west side of the sea level canal, as de Lesseps started to build it. Moreover the canal would only have a bottom width of 150 feet, except in the Culebra cut where it was proposed to make it 200 feet.

This type of canal would be open to all the objections brought against the lock type, and it would not be one half so efficient. The dam, with the Gatum Lake, controls the Chagres and makes it an efficient servant instead of a dangerous enemy. Instead of a narrow, crooked ditch with currents and counter-currents to make it dangerous to navigation, we have a broad and safe lake with no current at all. Instead of a carefully thought out and well matured plan, we would have only an idea even the authors of which are not in accord as to the means of carrying out.

There is only one thing to be feared in the lock plan, viz., earthquakes—and that danger is very remote, and if a bad one occurred it would be equally disastrous to the Gamboa and other dams, as to the dam at Gatun. One of the reasons urged in favor of the Panama route was the freedom from earthquakes in that region. But the advocates of the sea level, or rather the opponents of the lock canal, pay heed to none of these considerations. They fill the air with denunciations of the dam and locks, and clamor for a sea level canal, whatever it may be—only a sea level canal!

I wish to acknowledge my indebtedness to Senator Thomas C. Carter, to Capt. F. C. Boggs of the Isthmian Canal Commission in Washington, to Governor J. C. S. Blackburn of the Commission in Panama, to Lt. Col. Hodges, to Major W. L. Sibert and Major I. P. Jervey and Col. Gorgas. I wish to thank these gentlemen for their kindness and unfailing courtesy and readiness to give any information in their power. In fact, we found all, officers or employees, high or low, most ready to give us any facts or figures which we might ask for. I shall look back with pleasure to the time I spent on the Isthmus viewing the grandest engineering work of civilization.

I have tried to set before you the condition of affairs on the Isthmus and show the advantages of the adopted plan. I have done this, I know, very imperfectly, but it does seem to me that the testimony of the gentlemen engaged in this work, in view of what they have already accomplished, of their high professional standing and of the careful and painstaking investigations they have made, that their testimony and opinion should outweigh the opinions of those who, in criticizing, have no definite idea of what should be offered in exchange.

PEAT AS FUEL.

ORIGIN AND CHARACTER.

Peat is partly decomposed vegetable matter that has formed either where the ground is saturated with water most of the time or where it is permanently covered with water. It is the dark-colored or nearly black soil found in bogs and swamps, commonly known as muck, although technically a distinction is made between peat and muck, the latter name being restricted to those forms of swamp deposits that contain too much mineral matter to burn freely. Dry peat may be very fibrous and light colored, or compact and structureless and dark brown or black. It is usually somewhat lighter in color when dry than when freshly dug. When wet it contains as a rule from 80 to 90 per cent. or more of water; that is, a short ton of wet peat rarely contains more than 300 pounds of dry peat and may yield as little as 100 pounds. In the wet condition it is entirely non-combustible, and the various processes by which it is prepared for use or market consist principally of methods for ridding it of water quickly and cheaply and for increasing its fuel efficiency and transportability.

A VALUABLE RESOURCE.

The great peat deposits that are widely scattered in the northern part of the United States have at various times aroused strong public interest. In the winter of 1902–3, for instance, when the strike of the coal miners in the anthracite region of Pennsylvania brought the country to realize that it was to a large extent dependent on these miners and their employers for an important part of its fuel supply, a number of writers familiar with the conditions in the countries of northern Europe called attention to the fact that those countries, possessing a climate much more severe than ours, were using

great quantities of peat for fuel, while in this country, although the material was abundant, it had only exceptionally been prepared for use and then in the crudest way. During the next few months many experimental and speculative plants were established to convert peat into fuel, but unfortunately many of these attempts were financially unsuccessful, and as the strike was soon over and coal could again be had at reasonable prices and very little peat fuel was put on the market at any price, interest in peat waned and at the present time the public is almost indifferent to it. In the few places where it can be purchased, however, it finds a ready sale and is thoroughly satisfactory for all domestic uses.

An interesting account of the nature, origin, and uses of peat appears in a report by E. S. Bastin and C. A. Davis, on the peat deposits of Maine, which has just been published by the United States Geological Survey as Bulletin 376. Copies of this bulletin may be obtained free of charge by applying to the Director of the Survey at Washington, D. C.

PRODUCTION OF SLATE IN 1908.

VALUE OF OUTPUT.

The value of the slate quarried and sold in the United States in 1908, as reported to the United States Geological Survey, amounted to $6,316,817, an increase of $297,597 over the value of the 1907 output—$6,019,220—in spite of the general business depression which prevailed during the latter year.

This increase was in the production of slate for roofing, most of the slate quarried in this country being used for that purpose. In 1908 the quarries yielded 1,333,171 squares of roofing slate, having a total value of $5,186,167 and an average value of $3.89 per square. In 1907 the roofing-slate output was reported at 1,277,554 squares, valued at $4,817,769, or $3.77 per square. The increase in the output of this material in 1908 was therefore 55,617 squares in quantity and $368,398 in value.

The value of the slate quarried for other uses—such as blackboards, school slates, flooring, sinks, and laundry tubs, sanitary ware, table tops, mantels, and hearths—decreased from $1,201,451 in 1907 to $1,130,650 in 1908—a loss in value of $70,801.

PRODUCING STATES.

The States producing the largest amount of slate are Pennsylvania and Vermont. Pennsylvania, whose output in 1908 was valued at $3,902,958, furnishes more than half of the roofing slate and of the milling stock and is the only State reporting a production of blackboards and school slates. About one-fifth of the milling stock and more than one-third of the roofing slate were quarried in Vermont, whose output in 1908 was valued at $1,707,616. The other States producing slate in 1908 were Maine, whose output was valued at $213,707; Virginia, with an output valued at $194,356; New York and New Jersey, with an output worth $133,494; Maryland, which contributed $102,186 to the total value for the country; California, whose production was valued at $60,000; and Arkansas, with an output valued at $2,500.

IMPORTS AND EXPORTS.

But little slate is imported into the United States, and the exports, which reached a considerable amount during the strikes in the Welsh quarries, have decreased so that they are unimportant as compared with the total output.

REPORT IN PREPARATION.

The Survey has in preparation a report on the slate industry of the United States in 1908, which will be published as an advance chapter from "Mineral Resources of the United States, 1908." This report will contain, in addition to the statistical matter, a discussion of the uses of the slates of the various States by T. Nelson Dale.

PEAT DEPOSITS OF MAINE.

REPORT BY THE GEOLOGICAL SURVEY.

As part of an extended inquiry into the peat deposits of the country, the United States Geological Survey has recently completed an investigation of the peat bogs in Maine. The field studies of these bogs were made chiefly by E. S. Bastin, of the Survey, in the summer of 1906, but a few of the bogs were examined in the summers of 1907 and 1908 by C. A. Davis, principally for the purpose of determining what plants had been most active in forming the peats. The expense of the work was shared by the Federal Survey and the Maine State Survey Commission. The report which the United States Survey has recently published as Bulletin 376, bearing the names of Messrs. Bastin and Davis as joint authors, presents an estimate of the extent and value of the more accessible peat deposits of the State.

EXTENT AND VALUE OF THE DEPOSITS.

The field test and the analyses recorded in this report show that Maine possesses immense resources of peat of excellent quality for fuel and other purposes. In the southern and eastern parts of the State deposits of good quality are most abundant in Androscoggin, Kennebec, and Penobscot counties, and especially in Washington County. In the northern part of the State tests were made only in Aroostook County and along the Bangor and Aroostook Railroad. Peat resources as great as or greater than those of southern Maine undoubtedly are to be found in the forested lake district of the northern part of the State. Their utilization is so remote that testing them for the purpose of the report was not warranted, but they must be considered in estimating the total peat resources of the State. These resources, except for experimental plants near Lewiston and Portland, are at present undeveloped.

The area of peat land actually tested in preparing the report is estimated at 25 square miles. The average depth of the peat is about 10 feet. It is calculated that the bogs tested are capable of yielding at least 34,000,000 short tons of air-dried machine peat, which, at $3 a ton, would represent a value of more than a hundred million dollars. It is probable that the deposits tested from only one-tenth to one-fifth of the total peat resources of the State.

NATURE AND USES OF PEAT.

In most of the bogs which show any considerable amounts of peat the material is sufficiently decayed for use as a fuel, but in few places the peat is in the main not well decayed and is so fibrous that it is better suited for such uses as the manufacture of paper, moss litter, etc., than for fuel.

The report contains an interesting discussion of the nature, origin, character, and economic value of peat deposits. The factors that must receive careful consideration before any deposit of peat can be successfully exploited on a commercial scale are also discussed. The failure to consider some or all of these factors in their interrelations accounts for most of the marked lack of success in the attempts to use peat in this country. Properly prepared peat is a good and efficient fuel and it may be used effectively in a number of manufacturing industries. The unfavorable outcome of most of the business ventures connected with its preparation and utilization has been due, not to causes inherent in the material itself or in the product from it, but to easily preventable errors, of which the most common has been failure to take advantage of the great store of experimental and business data accumulated in Europe during the last century.

Copies of Bulletin 376 may be obtained free of charge by applying to the Director of the United States Geological Survey, Washington, D. C.

FRANKLIN INSTITUTE

THE MIXTECA COUNTRY IN THE STATE OF OAXACA, MEXICO.

BY

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Past President Franklin Institute; American Institute of Mining Engineers; and Engineers' Club of Philadelphia.

Mexico is a land of surprises, a country of extremes, a nation of contrasts—where the old and the new, the poor and the rich, the crude and the refined are neighbors, and where ultra conservatism is elbowed by evidences of modern progress.

The topography in 75 miles jumps from ocean level to the snow-capped summit of Orizaba, 17,362 feet above that datum, and the climate varies from perpetual summer of the Torrid Zone to perennial snows on Popocatepetl, its neighbor Ixtaccihuatl and other mountains. The flora include cacti of the desert, wheat and maize of the temperate zone, cotton, sugar, coffee, and luxuriant tropical growths with flowers and orchids in endless variety. The forest products of the highlands embrace oaks, pines, palo-blancho, mesquite and huisachie, while the hot country supplies rubber, ebony, mahogany and other hard woods. Many stream beds are dry "arroyas" or "barrancas," except during brief intervals when flood conditions temporarily transform these into rushing torrents; while the discharges of other rivers are fairly maintained throughout the year, and most watercourses have carved rugged cañons in the rocks or deep gashes in the alluvial plains.

The topographical features have interfered with close associations existing between different portions of Mexico, for the country may be divided into the "tierra caliente" and "tierra alto," the former comprising relatively narrow strips of hot lands bordering the Gulf of Mexico, the Caribbean Sea and the Pacific Ocean, the latter forming the main plateau bounded by the two sierras, Orientalis and Occidentalis. It is these mountain ranges

and intervening long desert stretches which have made intercommunication difficult.

The sierras approach each other near the City of Mexico, and the adjacent states, which are largely mountainous, maintain a population whose density is greater than that in other portions of the Republic.

The people, mainly an assemblage of descendants of numerous tribes, many speaking ancient languages, are apparently united and patriotic in supporting a government nominally republican but by reasons of conditions nearly monarchial, and although our near neighbor, we fail to recognize that few countries have had the soil more thoroughly stained by the blood of their people than the Republic of Mexico.

The genesis of Mexican history is shrouded in uncertainty, little being known as to the origin of the Toltecs, Aztecs, Mixtecas, Zapotecs, and other ancient peoples who came from unknown lands, but we are told of constant internal warfare and of the sacrifice of prisoners. Then, nearly 400 years ago, Cortez with a few hundred followers captured Mexico with its millions of people, who for three centuries were dominated by rapacious rulers and slaved to fill the coffers of Spain. The tales of rapine and plunder, of robbery and murder, done with the connivance of the ruler of Spain, or often in the name of the Church, tell how the inhabitants of Mexico were ground under the heel of oppression until their number was greatly reduced.

In September, 1910, Mexico will recognize the centennial of its independence, or rather celebrate the hundredth anniversary of Hidalgo's first stroke for freedom, as for a half century subsequently the country was in the throes of war to establish a government in which the people had some voice, no less than forty rulers, usurpers, governors, dictators, presidents, and emperors having disturbed the nation during this period. Hence the peaceful development has been confined to the latter part of the century which will be celebrated. Eleven years elapsed between the bold effort of Miguel Hidalgo and the breaking away from the Spanish yoke under Emperor Iturbide, and three years later (1824) Guadaloupe Victoria was proclaimed the first President of Mexico.

A large proportion of the fifteen and a half million population can be considered as very poor, and yet within a genera-

tion Mexico has passed from the verge of bankruptcy to a position among nations of the Western Hemisphere where its credit is second only to that of the United States.

Although most of the 11,000 miles of railway have been constructed within twenty-five years, these and the telegraph lines are under government control, and, while largely dependent upon foreign capital for development of its resources, Mexico maintains a tariff which protects domestic manufactures and products.

Its system of compulsory education is expanding and instilling among the people ambition to better their condition. The

FIG. 1.

Girls' school and teachers in City of Tlaxiaco, illustrating the characteristic features of the children.

peons, accredited as lazy, cheerfully perform tasks demanding physical exertion which would appall our average workmen, and, proclaimed as dishonest, are faithful in discharging individual trusts committed to them. In the city streets elaborately gowned women are brushed by the barefoot Indian mother whose scanty costume is shared by an infant swung on her back in a "rebosa" and the burro with a pack larger than himself, or the "cargadors" bearing heavy or cumberous burdens appear as competitors to modern express wagons, or as contrasts with elegant equipages or automobiles.

Mercantile houses and offices in cities close for two hours at

midday, nominally for "siestas", but few American shop-keepers or merchants devote more hours per day to counter business than the average Mexican merchant. However, the numerous "fiestas" recognized as partial or full holidays reduce the average of shop hours.

As a rule the rich have large wealth, while the poor have little, if any, possessions beyond the limited wardrobe which serves as clothing, ample for the midday warmth, but apparently insufficient protection for the cool night air, for in much of Mexico one seeks the shade while the sun is shining, but sleeps under blankets at night.

FIG. 2.

Peon children in the Mixteca country.

It is not unusual in "casas grandes" to have formal dinners of many elaborate courses in the middle of the day, which include the plebian "tortillas" and "frijoles", the staple support of the peons throughout Mexico.

Appreciating the general conditions outlined, it was not surprising to find within less than 300 miles of the capital of the Republic a section of which few in the City of Mexico know little except by hearsay, but which offers much of interest in its history, topography, products, its people and their habits.

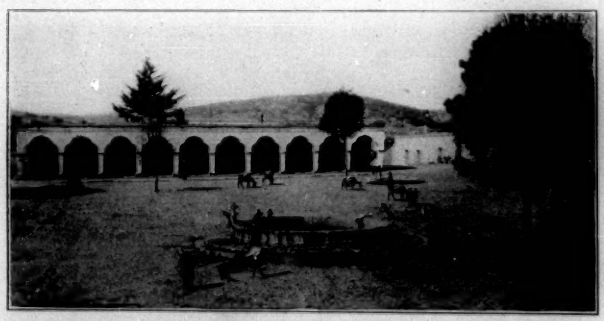
Southeast of the capital lies the State of Oaxaca, fronting on the Pacific Ocean for 300 miles, but of its total area of 35,392 square miles (equivalent to four-fifths of the area of the State

of Pennsylvania) the bulk is mountainous, the average elevation above sea-level approximating that of its historic capital, Oaxaca, 5000 feet.

The population of the State in 1900 was 948,633.

The only railroads within the boundaries are parts of the Vera Cruz and Pacific, the Tehuantepec, and the Mexican Southern roads (the latter connecting the cities of Puebla and Oaxaca); the total mileage within the State (370 miles), reaches but a small percentage of its area, while the extent of wagon roads in the mountains is limited. These conditions hold true

FIG. 3.



Fountain in Market place, City of Tlaxiaco. Three of these fountains supply the inhabitants with water which is carried to their homes in vessels of various kinds.

for the neighboring State of Guerrero, which like Oaxaca is mountainous, with but one railroad and few wagon routes within its borders.

In the central western portion of the State of Oaxaca, known as the Mixteca country, live the Mixteca people who claim to trace the history of their race to the sixth century of the Christian era, a mountain people whose pueblas and towns are located in valleys of 6000 to 7000 feet altitude with surrounding mountains 2000 to 4000 feet higher. The alternation of mountain ranges and fairly well watered valleys presents superb vistas from the crests of divides, some showing beyond the valleys an apparent succession of ranges with peaks or individual sierras overtopping their neighbors, while views from other passes pre-

sent such variety of form and direction as to merit the description of "scrambled mountains." In one valley is seen corn and wheat as predominating, the mountain sides bearing trees of the temperate zone, while another, which is at lower average altitude, exhibits large areas of vivid green sugar-cane fields, fringed with palms or banana trees.

The visit to the Mixteca country was made via Parian, a water station on the Mexican Southern Railroad, 36 miles north of Oaxaca, elevation 4900 feet, where the horse trail was taken westward over the mountains, the objective point being the City of Tlaxiaco, 90 miles distant. This trail, on most of which wheeled vehicles cannot be used, traverses a series of steep mountains with intervening valleys, and in the latter are located the towns of Nochixtlan, Teposcolula and a number of minor settlements; the passes over the mountains ranging from 8000 to 8800 feet above sea-level.

Nochixtlan, a town of 3000 inhabitants, located 7000 feet above sea-level and 25 miles from Parian, is supported by liberal nearby areas of grain and corn, by tropical products from the lower valley, and by pack-train traffic passing through it to and from the railroad. The crests of a group of hills, just west of the town, are covered with innumerable pieces of broken pottery, much of it evidently of great age, and from among this accumulation many small carved idols are obtained. Some of these idols have faces and poses suggesting Egyptian origin, others possess features of decided Asiatic cast.

Teposcolula, 30 miles west of Nochixtlan, evidently the remnant of a more pretentious settlement, is claimed to have been the ancient capital of Oaxaca, and the remains of a magnificent church edifice attest the important position the town formerly held. Fluted stone columns, 20 to 30 feet high and 30 to 40 inches in diameter, support by ornamental groined arches the damaged roof of the sacristy, while similar columns and arches define portions of what were the nave and transept, and the dome, which is elaborately carved, is falling to pieces, fairly good-sized trees growing from it. The date of construction is unknown, but an adjoining pretentious church edifice now in use is claimed to have been built in 1763, largely from material obtained from the older church. Appearances suggest that, like many other buildings in Mexico, this cathedral was never completed, but the architec-

ture and masonry work equal what we consider remarkable in modern times, and, when it is remembered that each part had to be made of a size which could be transported from distant points on animals, the fitting together of these represents intelligent design, great skill, patience and enormous expenditure of labor.

Another instance indicative of the former importance of this section of the country is in the settlement of Santa Maria Tiltepec, at the base of the mountain separating the valleys of the Nochixtlan and Huajuapam rivers, where there is a large church

FIG. 4.

Transportation methods along a trail in the Mixteca country.

whose facade and sides are replete with carved stone work. It bears the date 1689, and, as it was probably a number of years in construction, was being built at the time William Penn settled in Philadelphia. The exterior of the building, the liberal display of gilded ornamentation of the interior, and the elaborately decorated organ, are in marked contrast with the surrounding habitations, consisting of some two-score huts with adobe or cane sides and roofs thatched with split aloe or palm leaves.

At Teposcolula the main trail forks, one branch passing southwest to Tlaxiaco, the other northwest to Huajuapam, the two prominent cities of the Mixteca country.

In towns and villages a few "carretas" drawn by oxen were

in evidence, but these are employed only on the streets or on adjacent farm lands in the valley, for even these crude wooden constructions, in which no iron is used, cannot cover the steep, rough and often narrow trails across the mountains.

Tlaxiaco, a progressive town of 8000 inhabitants, with substantial buildings, is 90 miles from a railroad or from any continuous highway upon which wheeled vehicles are used, and nearby settlements add several thousands to the town's importance. It is well built, having some handsome houses and large stores, supporting an electric plant for street lighting operated by steam engines supplied by a 30 horse-power boiler fired with wood, and telegraph and telephone are also installed. The boiler, engine, and generators were carried or dragged to the town and among cumbersome furniture which one is surprised to find, owing to the difficulty of transportation, are pianos, billiard tables, or large mirrors, and the whirr of the sewing machines and click of type-writers are in evidence. On Saturdays the broad market place is a scene of great activity, when pottery-makers, weavers of "sarapes", "rebosas", "serviettas", baskets, and hats, iron workers, wood choppers, charcoal burners and farmers, the latter with his maize and "zacate", barter their products for meat, fresh vegetables, tropical fruits, skins, sugar cane, "pulque" and "aquadiente." The attendance ranges from 3000 to 4000, making the scene active and alive with color, and some vendors travel for two or three days to reach the market.

A purchaser entering a Tlaxiaco store finds many surprises in the extent and variety of stock carried, and the number of sewing machines sold in this Mixteca country is sufficient to encourage the maintenance of special depositories, the noise of the shuttle often coming from a one-room adobe or cane hut with thatched roof far from the towns.

A ride in one of the two passenger wheeled conveyances of which Tlaxiaco boasts was a special compliment tendered by a wealthy merchant. The road was rocky and rough, but two strong mules drew the buckboard, for such it was, through the city and out upon the hill on which San Pedro, the ancient city, formerly stood. With this exception no vehicle for travel was seen until, after following the trail for 200 miles, a "diligencia" drawn by five mules was utilized to climb a steep mountain face by a zig-zag road which in five miles overcame a difference in altitude of 1500 feet.

A collection of adobe huts, a cemetery, and a church cover the site of San Pedro where General Porfirio Diaz routed the allied French and Austrian troops in 1866, a location which justly wins for Tlaxiaco the term "Buena Vista," for there are grand mountain views on all sides. When the writer subsequently informed President Diaz of this visit, the soldier immediately overshadowed the statesman, as with sparkling eyes and dramatic gestures the veteran recited details of the warfare carried on among the mountains of the Mixteca country, and told of bold strategic methods by which forces greatly superior in number and equipment were defeated.

In the valleys, which have elevations ranging from 5000 to 7500 feet and are fairly well watered and cultivated, corn, wheat, and some sugar cane are the staple products. In towns adobe dwellings and stores and the ubiquitous Mexican churches are in evidence, but the majority of the people live in pueblas, collections of adobe or cane huts, thatched with maguey or palm leaves, and the most of the population are known as Mixteca Indians. Outside of the larger cities but little Spanish is spoken, the language of the Mixtecas being quite distinct, sometimes suggestive of the Orient, and occasional types of Indians resemble the Asiatics.

Some of the Mixtecan words and their equivalents in Spanish (the language which predominates in Mexico) and in English are:

English.	*Spanish.*	*Mixtecan.*
River	Rio	Yuté
House	Casa	Vee
Water	Agua	Hindute
Tree	Arbol	Ñutu
Charcoal	Carbon	Ticalliñútu
Bread	Pan	Yxtatila
Corn-fodder	Zacate	Dndojo
Trail	Camino	Hichi
Man	Hombre	Te

These apply to the Mixteca country only, for within a few leagues other dialects differing in many features prevail.

The triumvirate honored by patriotic Mexicans consists of Hidalgo, Juarez and Diaz. Of these President Diaz was of Mixtecan parentage, and his tutor Juarez came from the neighboring Zapotecs. The President's familiarity with the Mixteca country, its mountains, streams, towns, pueblas and its trails,

was made apparent in two interviews in which he showed an intimate knowledge of conditions and resources. As a soldier he traversed the mountains of Oaxaca, and among the engagements mentioned on his military record are those of Nochixtlan, Huajuapam and Tlaxiaco.

In a country remote from avenues of transportation, and where mountains interfere with constructing wagon roads, crude methods of manufacture, agriculture and industry are to be expected. A soil fertile by nature is limited in production by shallow cultivation with the wooden plow. The clip from herds

FIG. 5.

Ferreria (Catalan forge) in Oaxaca. Note the water-fall in back of the building which furnishes power to operate the hammer and water wheel and also for blast by means of a trompe.

of sheep and goats which range the mountains and by devouring the younger growth prevent forest reproduction, is carded, spun and woven by hand into articles for personal wear and domestic use.

Iron ore, won from deposits which have large reserves of excellent mineral, with charcoal, made in the woods in small meilers, is fed to open forge fires, both ore and fuel being transported in sacks on burros. A column of water falling in a wooden trompe produces blast to accelerate the fire, and the loupe when completed is wrought under a helve hammer operated by a water wheel, the bars or anchovies being sold in towns at from 4 to 6 cents (gold) per pound. The abundance of iron ore and the un-

wrought deposits of coal in the Mixteca country give promise of a more extensive modern iron industry in the future.

The coal is apparently in the upper Jurassic formation, and in this respect differs from that now mined from the cretaceous horizon of Northern Mexico. The mineral from each of three basins explored is classed as bituminous, carrying considerable ash, but one section in Western Oaxaca produces coal, made dense probably by compression until it resembles anthracite and burns without smoke. The extent of this basin is being tested by the Oaxaca Iron and Coal Company by numerous exploratory

FIG. 6.

Lumps of coal at the mouth of an exploratory drift near Tezoatlan, Oaxaca. The wheelbarrow is used under protest, the natives preferring to handle the coal in crude litters as shown in the background.

drifts, supplemented by two diamond drills which have been carried over mountain trails to the workings.

The topographical and geographical location of the Oaxaca coal, 6000 to 7000 feet above sea-level, and 300 miles from the City of Mexico, whose altitude is 7500 feet, as compared with the Coahuila coal from Northern Mexico, elevation 1500 feet and distant 830 miles from the capital, offer inducement for their development, and reconnaissance indicates that by routes approximately following water courses satisfactory railroad connection

can be made with the Oaxaca coal fields, and that this may be extended to the Pacific coast.

The mountains of Oaxaca also yield ores of the precious metals, of antimony, copper and lead, some of which are won, transported and smelted by crude methods, while others are exploited and treated with modern equipment.

Some contrasts in the Mixteca country are most pronounced; in the treatment of sugar cane, one may see in use crude wooden or stone rolls rotated by animal or water power, and all intermediate methods between these and modern mills thoroughly

FIG. 7.

Band at City of Tlaxiaco. Note modern instruments, youthful performers, leader, and patron to whose generosity the band owes much of its success.

equipped, the latter, however, being convenient to railway transportation.

That the Mixtecans as a rule are industrious was evidenced by the many who, while directing pack trains over the trails, were weaving hats or mats, and by the sound of the loom, or even the modern sewing machine in mud or cane shacks. Their physical endurance is illustrated by bearing heavy burdens for many miles, over rough trails, keeping up a fast trot the while.

Like most Mexicans, the people are fond of music, and the large towns support good bands, while smaller settlements each have an orchestra of some kind. In Tlaxiaco serenades were tendered by orchestra and by band, the latter, having 30 members

(a number of whom were boys) supplied with instruments familiar to ourselves, rendered popular and classic music with excellent effect from scores illumined by candles. On another occasion the orchestra from Tezoatlan crossed a mountain trail for 15 miles to serenade the camp; one of the numbers played being a tuneful composition by a member of the orchestra.

A daily wage rate of 50 centavos (25 cents gold) does not permit these Mixteca bands and orchestras the luxury of uniforms, hence the favorable impression develops when hearing well-known selections played in good time and tune by men and boys clad in linen trousers and blouse, with a "sarape" on the shoulder, a "sombrero" on the head, and sandals on the feet. (The members of the band and the school-girls of Tlaxiaco were dressed for the important occasion when the photographs were taken from which illustrations were reproduced.)

The "sarape", a constant companion for all Mexicans, serves as a coat by day, a cover by night, and a cushion to soften the load carried on the shoulders; but in the rainy season a coat made of palm leaves is often worn.

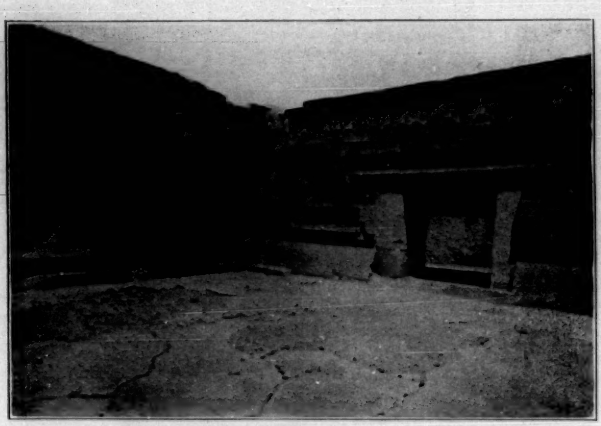
The Mixteca country is not peculiar in the loose sexual relations which prevail, due to the absence of legal or religious marriage formality among many of the poorer people, for in much of Mexico a large percentage of the children of the peons are illegitimate. It is claimed that in the divorcement of Church and State, which was enforced under Juarez, the government refused to sanction religious marriages owing to the political machinations which had been carried on by a then dominant clergy. But as the fee for a legal civil marriage, or that often demanded for a religious union, is beyond the ability of the really poor, these loose relations are maintained, winked at by both State and Church. Many of these voluntary ties apparently result in happy associations, and families seem to have bonds of affection; but if Mexico is to truly prosper, it will be necessary to have its coming generations imbued with the spirit which is expressed by the Commandment "Honor thy Father and thy Mother," and the respect and love which this spirit develops.

Although this section of Mexico is subject to wet and dry seasons, there is usually sufficient intermediate deposition of rain to permit of dry farming for grains, but where irrigation is practiced the crops are more diversified, larger, and dependable.

Many streams having their sources in the higher mountains are well maintained in the dry seasons, offering possibilities for water power improvement, and one of the camps on the Mixtepec River was at the mouth of a gorge whose nearly vertical walls rise for 200 feet above the stream which rapidly falls through the canon formed, suggesting a site for future hydro-electric installation.

Throughout the Mixteca country numerous churches, a large portion being pretentious, well-built structures, attest the exten-

FIG. 8.



Part of the Ruins of Mitla, Oaxaca, which have been excavated, showing the interior patio of the North Court, the absence of arched construction, the use of monolithic lintels, and some varieties of mosaics.

sion of the Spanish conquest to Western Oaxaca. Cities or important pueblos boast of several churches, and some large structures crown hills with but a scattered assemblage of huts for companions. The architecture varies but little from a general design which is repeated except in a few instances, but some of the carved stone work is unique.

Beyond the broken pottery, small stone idols, copper tools, and some evidently ancient foundations or walls, there are few reminders of the peoples who many centuries ago lived among the

mountains of Oaxaca. But noted relics of ability and industry evidenced by races whose history is now mere conjecture, are adjacent to the Mixteca country, such as the carved stones of Mont Alban, and the elaborate mosaic work at Mitla. More careful research may expose some of these ruins representing earlier civilization in the Mixteca country.

FIG. 9.

Detail from the Ruins of Mitla, Oaxaca, showing some of the mosaic work, so well laid and closely jointed as to have withstood the ravages of time for unknown centuries.

We of the United States, taught that our Continent when discovered by Columbus was peopled by ignorant savages, have difficulty in realizing that within less than thirty years after this generally accredited discovery, Cortez landed in Mexico and found in temples and structures, many of which were subsequently destroyed, evidences of what may be considered a civilization.

The illustrations presented are of work done before the advent of either Columbus or Cortez by inhabitants of Mexico whose history seems to have been forgotten.

The cliff houses and other scattered relics of an ancient people in what is now the United States may be increased by future investigation, but we cannot expect these to rival the ancient ruins of Mexico, Central or South America.

It is claimed that the Mixtecas formerly occupied most of the States of Oaxaca and Guerrero and a portion of Puebla but were driven from the Isthmus of Tehuantepec by the Zapotecs. They were devoted to agriculture while not engaged in warfare with the Zapotecs, Aztecs or other tribes, but succumbed to the Spanish. They, however, were prompt in aiding to drive the Castilians from the country, active in the overthrow of the Maximilian dynasty, and evidenced on many occasions the patriotism which seems to be inborn in mountain people.

The march of progress in Mexico has scarcely touched the Mixteca country, but it may be expected to ultimately extend throughout its mountains and valleys, developing its mineral wealth, waking the echoes by the locomotive whistle or automobile shriek, advancing the earning power of its people, and encouraging in them new ambitions. With modern equipment more intense agricultural development will result; with water powers improved, coal mined, and mechanical appliances installed, manufacturing will expand, and with increasing education the section may be expected to take decisive progressive steps.

TIMBER SEASONING AND WOOD PRESERVATION.

IN recent years the importance of preserving timber from decay by the use of various antiseptics has been generally recognized in the United States. The value of properly seasoning timber before such treatment is not so generally known, though it is one of the most important features of the treatment.

There are three main advantages to be derived from the proper seasoning of timber, namely: The increase in strength of the timber, the greater ease of injection of antiseptics for preserving the timber, and the saving in freight charges due to the decreased weight.

From thorough tests made by the Forest Service on various pieces of timber, it appears that thoroughly air-dry or seasoned timber has about double the strength of the green material. It is well known to all operators of wood-preserving plants that antiseptics are not only difficult to inject into green wood, but that it is practically impossible to obtain a uniformly satisfactory treatment of such material at an economic cost, for the purpose of insuring a prolonged life.

The last item would at first seem too trifling to be worthy of discussion, but from data obtained only recently it appears that western yellow pine lost 50 per cent. of its green weight after three to five months seasoning. This means a saving of 50 per cent. of the freight charges and a corresponding saving in the handling of the timber, and is therefore a far too important point to overlook.

Considering these three points, it will be seen that there is not only a material saving in the seasoning of timber, but also a proportionate increase in the value of timber as a structural material. The seasoning of timber is never an expensive operation, even when done artificially. In the southern parts of the United States, a satisfactory degree of seasoning could be obtained by exposure of the timber to the air for a period of three to six months. In some of the northern states, however, a somewhat longer period is necessary to secure satisfactory results.

MAINE COMMISSION REPORTS LOG RULES

THE Maine State Legislature in 1907 appointed a commission of three with the Forest Commissioner an ex-officio fourth member, to investigate the methods of scaling logs and lumber and to report to the next Legislature. On this Commission William J. Lanigan of Waterville, Fred A. Gilbert and Hosea B. Buck of Bangor, and Edgar E. Ring, Forest Commissioner, of Orono, were appointed by Governor Cobb. It is a commission of practical business men from wood-using industries. After holding hearings in the different lumbering districts of Maine, the following conclusions were reported in substance:

"The method of measuring manufactured lumber seems satisfactory and no change is recommended.

"The lack of uniformity in methods of scaling logs leads to great confusion and general dissatisfaction on the different rivers in Maine.

"The log rules in use, especially by the New Hampshire and the Maine or Holland rules, give fair results only for short logs, but are unsatisfactory for longer logs.

"The board foot is not the proper unit for log measure, since it is relevant only in case of lumber manufacture, but is entirely irrelevant in pulp, staves, veneer, and other industries.

"The cubic foot should be the unit of measure, and each manufacturer should calculate the product he could manufacture in board feet, pounds of pulp, number of staves, and square feet of veneer, and fix the price accordingly.

"The contract logger figuring in cubic feet would then be paid according to the weight he handles, whether the logs are large or small. In contracting by the thousand board feet, as is now done, he handles a larger weight of small logs per thousand than of large logs.

"The Commission recommends the substitution of a cubic foot caliper rule as the legal rule for Maine, arguing that besides applying to all industries involved it would aid economical logging and full utilization of material."

It is very evident that if log measurement is to be standardized for the entire country the cubic foot caliper rule applied at the middle of the log will be applicable for all States, all industries, all species, whatever their taper, and for long logs as well as for short logs. While the volume is not entirely exact by the midde diameter method for very long logs, the error is very small in favor of the buyer. But it gives by far the better result in comparison with end diameter measurement, even when the latter method makes allowance for "rise" or taper.

If the Maine Legislature adopts the rule recommended, the lumbermen and foresters say the State will be setting a standard rule that may be followed with profit by all the other States.

NAVAL STORES PRODUCTION IN 1908 AND 1907 REPORTED.

THE production of more than 36,500,000 gallons of turpentine and more than 4,000,000 barrels of rosin, with a valuation of more than $14,000,000 for the turpentine and nearly $18,000,000 for the rosin, summarizes the output of the Naval Stores industry for 1908, according to the preliminary report of the United States Forest Service just completed. The study was provided for in a special appropriation of $10,000 by Congress and the report contains the most complete and accurate statistics ever gathered for the Naval Stores industry in this country, and covers the production for both 1907 and 1908, giving comparative figures for the two years.

Of the eight Southern states, each producing more than 200,000 gallons of turpentine and 25,000 barrels of rosin, Florida leads the list with 17,030,300 gallons of turpentine in 1908 against 15,572,700 gallons in 1907, and 1,932,114 barrels of rosin in 1908 against 1,774,370 barrels in 1907.

Georgia, Alabama, Mississippi, Louisiana, North Carolina, South Carolina, and Texas follow in the order named. The comparative report of the production by states is as follows:

	1908		1907	
	Turpentine Gallons	Rosin Barrels	Turpentine Gallons	Rosin Barrels
Florida	17,030,300	1,932,114	15,572,700	1,774,370
Georgia	10,347,800	1,203,059	10,119,500	1,173,575
Alabama	3,744,050	446,909	3,544,300	418,496
Mississippi	2,277,850	277,704	2,232,500	255,307
Louisiana	1,696,250	195,804	1,134,100	126,346
North Carolina	732,300	131,907	916,400	168,561
South Carolina	559,800	72,125	586,950	75,057
Texas	200,650	28,661	74,350	7,609
	36,589,000	4,288,283	34,180,800	3,999,321

While these figures show an increase of 2,408,200 gallons of turpentine and 288,962 barrels of rosin for 1908 over 1907, there was a marked decrease in the value of the product for 1908 as compared with the preceding year. This was due to the great decrease in the prevailing prices for turpentine for 1908 and the slight decrease in the prevailing prices for rosin during the same year. The value of the product for the two years follows:

Turpentine, 1908, $14,112,377.32; 1907, $18,283,309.93; rosin, 1908, $17,783,509.61; 1907, $17,317,059.93; a difference in the value of the combined output of $3,704,482.93 in favor of 1907.

The figures used for determining the value of turpentine and rosin for the two years are based on the market quotations at Savannah, the recognized naval stores market of the United States. The average price received for turpentine manufactured in 1908 was $0.3857 per gallon, and in 1907 was $0.5349 per gallon. The average price received for rosin in 1908 was $4.14 per barrel and in 1907 was $4.33 per barrel.

The number of operations for the two years were distributed among the eight states as follows:

	1908	1907
Alabama	192	185
Florida	633	595
Georgia	666	643
Louisiana	25	22
Mississippi	94	93
North Carolina	41	48
South Carolina	37	39
Texas	8	4
	1,696	1,629

The increase in production for 1908 over 1907 was due to more favorable weather and labor conditions than to increased operations. But few operators increased their operations, owing to the disorganized condition of the market at the time operations commenced. Figures upon which the report of production for the two years is based were secured by a system of correspondence and personal visits to the points of production by agents of the Forest Service.

RUN-OF-MINE AND BRIQUETTED COAL ON LOCOMOTIVES.

EXPERIMENTS MADE BY THE UNITED STATES GEOLOGICAL SURVEY.

For the purpose of procuring data that could be used in estimating the value of the briquetting process as applied to American fuels, the United States Geological Survey, in co-operation with other interests, began in 1904, at the Louisiana Purchase Exposition, certain experiments involving the production and use of bituminous-coal briquets. Machines were installed at St. Louis, and later at Norfolk, for the manufacture of such briquets, and the output of these machines has been tested in locomotive service on several railroads in comparison with natural fuels. An elaborate and carefully executed series of tests involving the use of natural coals and of briquets made from the same coal, previously crushed, has been carried out on a locomotive mounted at the testing plant of the Pennsylvania Railroad Company at Altoona, Pa.; less extensive tests were made on several other railroads; and some preliminary experiments involving the use of briquets in marine service have been made in connection with one of the Government's torpedo boats.

A description of these tests, prepared by W. F. M. Goss, has been published by the Survey in Bulletin 363.

RESULTS OF THE EXPERIMENTS.

The results obtained in these tests are said to sustain the following general conclusions:

1. The briquets made on the Government's machines have well withstood exposure to the weather and have suffered but little deterioration from handling.

2. In all classes of service involved by the experiments the use of briquets in place of natural coal appears to have increased the evaporative efficiency of the boilers tested.

3. The smoke produced has in no test been more dense with the briquets than with coal; on the contrary, in most tests the smoke density is said to have been less when briquets were used.

4. The use of briquets increases the facility with which an even fire over the whole area of the grate may be maintained.

5. In locomotive service the substitution of briquets for coal has resulted in a marked increase in efficiency, in an increase in boiler capacity, and in a decrease in the production of smoke. It has been specially noted that careful firing of briquets at terminals is effective in diminishing the amount of smoke produced.

6. In torpedo-boat service the substitution of briquets for coal improves the evaporative efficiency of the boiler. It does not appear to have affected, favorably or otherwise, the amount of smoke produced. The briquets used in this series of tests were of a form requiring considerable bunker capacity for their storage, but as the form of the briquet is a detail entirely within control, this objection need not apply to the use of briquets in actual service.

Mr. Goss's report contains also a brief account of the briquet industry in Germany, Belgium, and France.

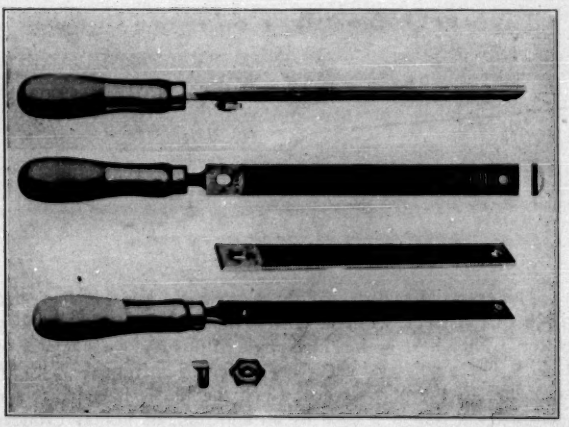
COMMITTEE ON SCIENCE & THE ARTS

VERNAZ MILLING FILES.

[Report of the Franklin Institute, through its Committee on Science and the Arts, on the Milling Files invented by Alexis Vernaz of Yverdon, Switzerland. Sub-committee: William H. Thorne, chairman; Lucien E. Picolet, George S. Cullen. No. 2445.]

THIS file is the result of an effort on the part of Alexis Vernaz of Yverdon, Switzerland, to save from the scrap-heap a large lot of accidentally hard castings. It was so successful

PLATE I.



that it has been patented in England, France, Belgium, Germany, Austria, Switzerland, Italy, Canada, and the United States. The latter patent is No. 807,143, dated December 12, 1905. One of the claims of this patent is: "A file provided with teeth cut in the form of arcs having their bases (chords) located rearwardly with respect to the cutting edge of the teeth."

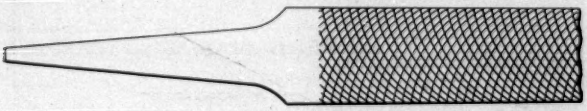
The Vernaz file is illustrated by Plate I.

In looking up the past history and evolution of the ordinary file we have found nothing which is not covered by the dictionary definition: "A steel instrument having raised cutting edges made by the indentations of a chisel." One patent, however, No. 44,724, dated October 18, 1864, granted to H. A. Harvey, contains a claim which in itself was rather startling: "Making the teeth of files in segments of circles extending across the face, substantially as and for the purpose specified." The records of this patent were destroyed in the fire at the Patent Office, so that all we have is the summary in the *Official Gazette*, the drawing in which shows that it has no bearing on the case (see Plate 2).

Plate-2

CIRCULAR TOOTH FILE.

U.S. PATENT NO. 44724 - 18TH. OCT. 1864 TO H. A. HARVEY.



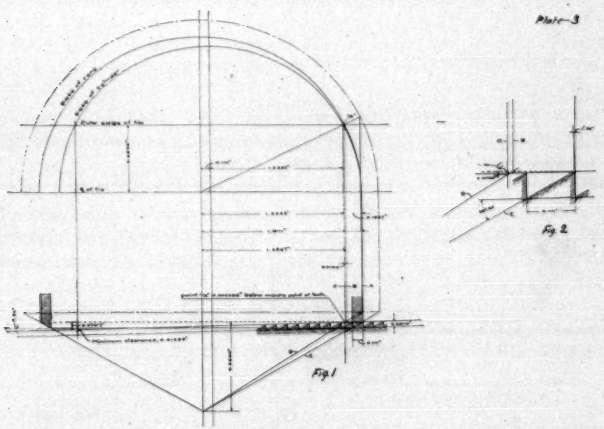
Making the teeth of files in segments of circles extending across the face substantially as and for the purpose specified.

The essential features of the Vernaz file are the shape and depth of the teeth, which are in section like those of a milling cutter. They have an included angle of 60° and a front rake of 1½°. The number of teeth per inch varies from 6⅔ to 16 according to the purpose for which the file is intended. The teeth are cut one at a time by an end mill, or hollow cylinder of 2½ to 3 inches diameter, with a conical end of 60°, the axis of this cylinder being inclined 1½° to the plane of the file and intersecting its centre line. Automatic machines rotate the cutters, feed them into the file blanks the proper depth, withdraw them, move the file one pitch, feed the cutter in again and so on.

The first impression was that the inclination of the axis of the cutter would produce a cutting edge on the file which would not be flat, but concave. This is, of course, true of the bottom of

the cut, but the top or edge being produced by the intersection of the conical face of the cutter with the cylindrical surface made by the preceding cut, was so doubtful that we have drawn it in true proportion three times natural size in order to accurately determine this point.

This is shown in Plate 3, in which the lines *C* and *D* are corresponding elements of the cylindrical and conical surfaces of the tooth at the edge of the file and determine the corner *A* of the tooth. These are shown in greatly enlarged scale in Fig. 2.

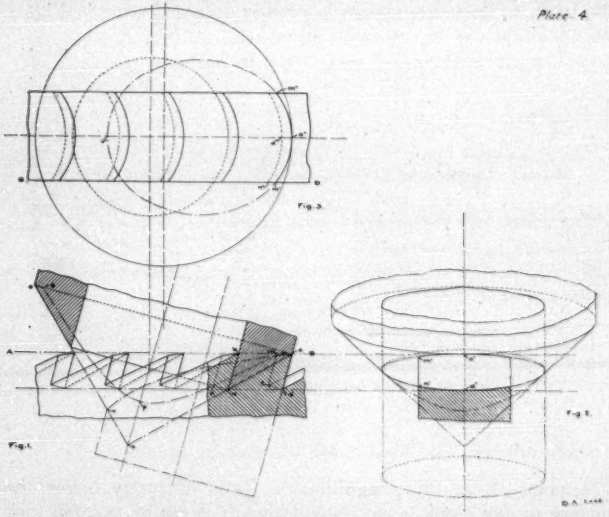


The point *A*, at this magnification, falls distinctly below the surface of the blank. By computation it is really .002286 inch below this surface, which is probably a benefit.

Plate 4 is drawn with a very different ratio of cutter diameter to pitch in order to exaggerate the conditions and to more clearly show the geometrical relationship between the shape of the teeth and the cutter. In this *cd* is an element of the cylindrical front of the tooth at its centre, and *ca* an element of the conical top; *na n'a'* show the elliptical bottom; *mn* a portion of the hyperbola formed by the intersection of the conical surface with the plane of the side of the file; *cm*, *c'm'* show a portion of the line of intersection of the conical surface with the cylindrical

surface of the previous cut, and indicate how the point *m*, which is the corner of the tooth, drops below the top plane of the blank.

In practical tests we find that the circular shape of the cutting edges act normally to the cut whether the file is pushed straight or at an angle, and also that the relatively large pitch and depth of teeth prevent clogging and the necessity of cleaning, and produce a surprisingly smooth surface. The surface produced



on steel is smoother than that from an ordinary second-cut file, due to the fact that the latter quickly retains small chips of the steel in its teeth which scratch the surface.

On all fibrous and tenacious materials like wrought-iron, steel, brass, aluminum, and the alloys, the improvement over ordinary files was very marked, the cut being clean with no clogging and scratching. That the action is cutting and not abrading or scratching is shown by the chips, which under a magnifying glass are seen curled up and look as if made by a lathe or planing machine.

The verbal reports of machinists after trying these files, were found to be very unreliable by reason of their prejudices and indifference, but where any one of them had a real job of filing where metal was to be removed in good earnest he invariably became enthusiastic in his praise and was loath to part with the experimental samples.

Fortunately at this time a File Testing Machine built by Edward G. Herbert, Limited, of Manchester, England, was at the works of William Sellers & Co., Incorporated, of Philadelphia. They had just completed tests of 29 files of eleven different makes, the result of which they very kindly placed at the disposal of the committee, and also made a test of one Vernaz file which was submitted with the application. These tests were all made on standard cast-iron test bars of one inch square section. Since then, Tinius Olsen & Co. have taken the agency for the Herbert machine, and have tested for the Committee three Vernaz files on cast iron to compare with the Sellers tests, and three Vernaz and three regular commercial files on steel. The Vernaz and commercial files were bought in the open market to prevent any special preparation, and for the latter the best make known was selected. Thus there are records of 32 tests on cast-iron and six on steel.

The cast-iron test bars have the following composition:

Combined carbon	0.051	Sulphur	0.075
Graphite	2.988	Titanium	0.035
Silicon	1.915	Iron	92.400
Manganese	1.204	(Annealed for uniformity.)	
Phosphorus	1.332		

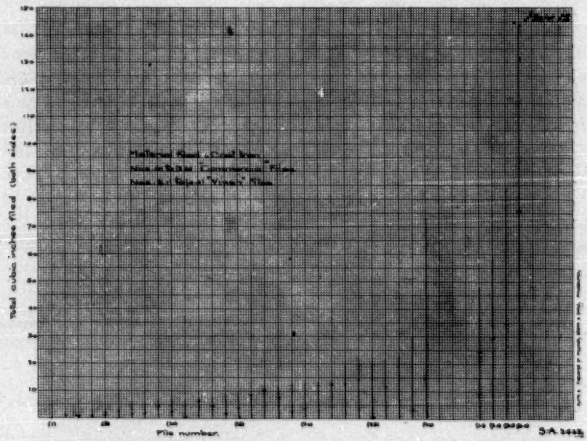
The steel test bars have the following composition: carbon 0.64, manganese 0.80, silicon 0.41.

The selection of the high carbon steel for the latter is due to the experience of Herbert & Co., who found that low carbon machinery steel clogged up the commercial files so very soon that any test was impracticable.

In the Herbert machine, the file is held firmly and solidly backed up in a sliding frame having a reciprocating motion of six inches. The end of the test bar, one inch square, is pressed against the file during its forward stroke and withdrawn on the return. The pressure is positive and can be altered to suit. In these tests it was 20 pounds on the cast-iron and 30 on the steel.

A chart is placed upon a drum which is so geared to the motions that its axial movement records the number of strokes and its circular movement the amount of metal removed. A fixed pencil, pressed against the chart, draws a curve, the abscissæ of which give the strokes, and the ordinates the length of the bar filed away. It is unfortunate that there was no means of also obtaining a record of the energy required for the removal of a given amount of metal.

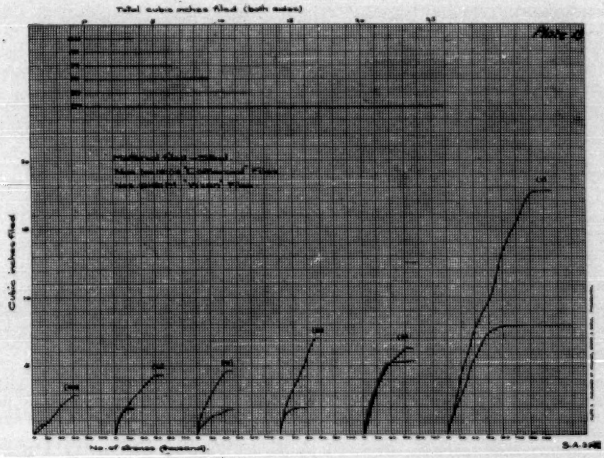
These charts, in which the personal element is entirely eliminated, show astonishing results. It being understood that



each test was continued until the file slid over the end of the test-bar without removing any metal, 28 out of the 29 commercial files on cast-iron ranged in the cubic inches of metal removed from 0.7 to 20.6, while one lone hero removed 73. The average cubic inches per ten thousand strokes varied from 1.4 to 6.34, but these figures did not correspond with the others, showing some to have better cutting qualities and others better endurance. Another curious feature was that very rarely indeed did the two sides of the file show anything like equality, the worst case being 20.6 cubic inches removed by one side and 0.4 by the other, the best case being 11.8 by one side and 10 by the other.

Of the 4 flat Vernaz files on cast-iron, the worst filed a total of 48.2 cubic inches, using both sides, and the best 143.75 cubic inches, and the variation between the sides was very slight, the worst case of variation being 49.1 for one side and 34.9 for the other.

On high carbon steel, the Vernaz files did not show such marked superiority, due probably to the fact that the best commercial files were selected to compete with them. The minimum and maximum figures for the commercial files were 3.6 and 6.4 cubic inches, and for the Vernaz files 9 and 25.8 cubic inches.



In this case, however, two out of the three Vernaz showed a marked difference in the two sides. Evidently the art of making files, after centuries of evolution, is still far from being an exact science.

The diagrams will graphically show these results. Plate 12 shows the results of the tests on cast-iron, and on account of the number of tests is arranged with vertical lines, the height of the line showing the total cubic inches removed by both sides of the file, and the cross-mark indicating the difference between the two sides.

Plate 13 shows the results on high carbon steel and is a facsimile of the lines drawn by the machine on the original charts, supplemented by horizontal straight lines showing the total cubic inches removed by each file.

In conclusion, the Committee considers that Alexis Vernaz has made the first radical, leading improvement in files for generations, and has done a service to the world, not only in presenting a new and efficient cutting tool for metals, to be operated by hand, but also in the impetus which the introduction of this tool will give to the improvement in cutting capacity and endurance of the regular type of files, and recommends the award, to him, of the Elliott Cresson Medal.

Attest: JAMES CHRISTIE,
Secretary.

Philadelphia, April 17, 1909.

GOVERNMENT STUDIES METHODS OF SEASONING EUCALYPTUS POLES.

THE government has undertaken a study to determine the proper method of seasoning eucalyptus poles, particularly those cut from trees which, owing to a large number of knots, will not make clear lumber. Such poles have shown a tendency to check and warp after being cut, probably due to improper methods of seasoning, which has been a great obstacle to their more extensive utilization.

Experiments will be carried on by the United States Forest Service to determine the method of seasoning which will prevent this checking and warping. One series will be conducted on the Sutro Estate which is in the fog belt, and another on the Pacific Land Investment Company's holdings at Newark, which is out of the fog belt.

Forty-eight growing trees, 13 inches in diameter and having a clear length of 34 feet, will be selected and marked by an officer of the Forest Service. These two groups will be handled in the same way, 12 trees of each group are to be girdled and allowed to die and season standing, with the bark on, and the other 12 will be felled and laid on skids in the open and seasoned in this manner. Six of the 12 felled trees of each group will be peeled, and the other six will be left with the bark on.

The skids will be so constructed that the poles will be at least one foot from the ground to allow a free circulation of air. The poles will be left on the skids for from 6 to 8 months, and observations taken as to checking, warping, shrinkage, and loss of weight. The same observations will be obtained from the standing poles, with the exception of the weight.

When a sufficient period of seasoning has elapsed, determined by the weight of the skidded poles, the standing poles will be cut and their weights found. The condition of these poles will then be compared with the condition of the skidded poles, and a proper method of seasoning outlined which will be available to all interested in the use of eucalyptus timber.

CORRESPONDENCE

"EARTHQUAKES IN THE LIGHT OF THE NEW SEISMOLOGY."

SECRETARY OF THE FRANKLIN INSTITUTE:

Replying to the article by Prof. Oscar C. S. Carter on "Earthquakes in the Light of the New Seismology," I wish to say that there are some points in the argument which appear to me to invite discussion. Before proceeding to analyze the statements with which I disagree, I wish to call attention to a quotation in Professor Carter's article to the effect that "An open-minded hospitality for new facts is essential to intellectual advance."

Passing over the first three theories regarding the condition of the interior of the earth, we come to the fourth, which Professor Carter says is probably the correct one, "and is, that the earth is solid on account of the enormous pressure of the rocks." "It is hot enough to melt rocks, but on account of the enormous pressure the material is pressed solid." There is no mention of the probability that a large portion of the earth ever was or may still be above its critical temperature.

I will introduce a definition of "critical temperature" taken from a standard work on Elementary Physics edited by Aldous, page 326. "For each gas there is a temperature called the "critical temperature," and when the temperature is above this point it is not possible to liquify it by any pressure, however great."

This important principle was discovered by Dr. Andrews. Substantially the same definition is to be found in all works on physics and therefore may be considered as true enough to form the basis of a theory. If there is a critical temperature above which gases cannot be liquified by pressure, then it must follow that any substance above its critical temperature is a gas, even if its density be twice or many times as great as the density of its solid or liquid forms. Modern science teaches that the atom is not the indivisible or incompressible ultimate that it has been supposed to be, and therefore a gas can have a density greater than its solid form.

If we can prove that any portion of the interior of the earth is above the critical temperature of the matter composing it, we will have proved that it is in a gaseous condition. We know that the elements can be rendered gaseous at the temperature of the electric arc, and we find that the temperature of the electric arc has been determined at from 3500 C. to 4000 C. Now if all these elements can be rendered gaseous in the electric arc, it is strong presumptive evidence that the critical temperature of all known matter is near 4000 C.

The next question arises is whether that temperature is reached in the interior of the earth, and if it is, at what depth?

Taking what Professor Carter says on the rate of increase of temperature with depth as representing the known facts in the case, and reducing the Fahrenheit to Centigrade degrees, and allowing for a gradual reduction in the rate of increase, I find that at a depth of 200 miles or less the critical temperature of all known matter is passed, and from that point on the interior of the earth must be in a gaseous condition or all our information about critical temperature is wrong.

Then the question is, how is it possible that a gaseous interior can be rigid?

Rigidity is a property of solids, acquired by a reduction of the amplitude of vibration of its molecules with relation to each other. To test this definition it is only necessary to heat a piece of iron in order to see how rapidly the rigidity decreases as the temperature rises, until when the amplitude of vibration of its molecules becomes too great to be resisted by coherence, the iron melts and becomes a liquid. Therefore, if there is a gaseous interior to the earth in which the pressure has increased the density beyond that of the solid condition of matter, the amplitude of vibration of its molecules with relation to each other must be less than when in the solid condition, and according to the above definition of rigidity it should be more rigid than a solid interior of the same composition. The critical temperature which exists at 200 miles below the surface evidently existed throughout the entire planet at an early state in its development from a nebula, and at that time the whole planet was gaseous, even as the sun is now.

Under such conditions, according to the known laws of diffusion of gases, each gas of which the planet was composed would diffuse throughout the entire planet from centre to circumference. The law referred to says, that in a mixed body of gases each gas diffuses throughout the entire space occupied regardless of density.

The gaseous interior which we have good reason for assuming to exist beyond a depth of 200 miles is but a remnant of a gaseous planet and must have within it some of each of the gases which diffused throughout the planet when in a gaseous condition. Have we any evidence that this is the case? It so happens that we have abundant evidence, but it has heretofore been misapplied and misunderstood.

The gases given off during earthquakes and volcanic explosions have been observed, and in the following selected cases from "Earthquakes and Volcanoes," by Mungo Ponton, F.R.S.E., will show that they play an important part in both phenomena.

"At Palermo in 1726, during a violent earthquake which shook down 1600 houses, the earth opened in one of the streets of the city and threw out burning sulphur with red-hot stones while the atmosphere appeared as if on fire. The flames issuing from the earth kindled the wood-work of the houses in the street and they were all consumed."

In the month of October, 1755, several strange meteorological phenomena occurred in the Spanish peninsula, such as frequent "halos around the sun and moon, numerous luminous meteors, and terrific thunderstorms with much rain. The waters both of wells and rivers became turbid and fetid; rats and reptiles came forth as if frightened, and domestic animals showed much uneasiness. On the first of the following month of November occurred the great earthquake of Lisbon."

An explanation of all of these strange phenomena except the luminous meteors is to be found in the effect of escaping gas, such as sulphuretted hydrogen and sulphurous acid and carbonic acid, from the interior, as a premonitory symptom of the coming shock which, as I shall show, is due to the sudden intrusion of a dike into a fault plane by the extrusive force of magmatic steam. The steam would naturally be condensed to water, and, added to the ground waters would, with its associated gases, render them turbid and fetid.

Under such circumstances the cause of alarm of animals living in burrows or holes is easily explained. The gases immediately reach their smelling organs and alarm them. The same is true of dogs and domestic animals that keep their noses on or near the ground, while man who walks on his hind legs, does not think of the gases as coming from the ground and is not so quickly warned as the lower animals. Where a large amount of such gases ascends through porous soil it might produce an effect on the atmosphere which would be apparent without causing any visible vent or opening in the earth.

"On the tenth of July, 1756, there were two sharp shocks at Lisbon, during which there rose from the ground a cloud of smoke that obscured the sun, and filled the air with a sulphurous smell."

"On the second of April, 1762, the coast of Chittangong in the north-east of the Bay of Bengal, was violently shaken. Many large openings were found in the ground from whence water and mud, smelling strongly of sulphur (H_2S) were ejected. A large river was dried up at a place called Bardavan, while at Bar Charra, near the sea, a tract of land sank down and was submerged, drowning 200 people and their cattle. Sixty square miles of coast permanently subsided, one mountain sank down until only its summit remained visible, while another disappeared altogether.

"Several other hills were rent asunder, and chasms from 30 to 60 feet wide were found. The towns upon the tract which subsided were overflowed and one was submerged upwards of 10 feet. This great subsidence was accompanied by a corresponding elevation of the ground in the island of Romree and Chuduba, lying to the southward."

The foregoing account is interesting as an example of how cracks *open* in nearly all earthquakes.

Now obviously cracks do *not* open without a competent cause, and I shall refer to this later as showing that they open because of an expansive force from the interior.

"Hungary was the scene of a succession of shocks in 1763, when many houses were overthrown in Comorn. There were formed in the earth large openings from which sulphurous vapors arose. Jets of water the thickness of a man's arm ascended from the Danube to a height of 30 feet, the water being mixed with sand and having a sulphurous smell."

"The coast of Caracas in South America and the adjacent island of Trinidad were violently convulsed in 1766, and the whole city of Cumana was reduced to ruins. The shocks were continued for upwards of a year, and were at first repeated almost hourly. There were frequent eruptions of sulphurous water from fissures in the ground, and an island in the Orinoco disappeared. Four years after, the western coast of St. Domingo was similarly agitated and its chief city, Port au Prince, nearly destroyed. There were found in the earth great clefts whence arose poisonous vapors that caused an epidemic; hot springs also arose in several places, but they proved temporary."

In the above we have again the cracks opening, gases escaping and hot springs resulting from the condensed steam which later disappear.

"The district of Guatamala in Central America was visited by successive shocks in 1773–1775. The city of Iago with all its inhabitants was engulfed in huge chasms which opened in the earth. The earthquakes were connected with volcanic eruptions in the neighborhood. A catastrophe similar to that of St. Iago occurred in 1780 in the island of Candia where, during a violent earthquake, the castle of Eropetre with its garrison of 300 Turkish soldiers and also thirteen small villages in the neighborhood, with their inhabitants, were swallowed up in chasms."

"Toward the end of 1797 the coast of Caracas was again convulsed and those portions of Cumana which had been rebuilt during the last thirty years were once more laid in ruins. On the shores of the bay of Caricao, immediately before the shocks, flames issued from the earth, followed by a noise like the bubbling of gas in water."

"During the summer of the following year, Tuscany was visited by a succession of shocks and the town of Siena was reduced to a heap of rubbish, deep chasms having been found in the principal square."

"In 1806 two severe shocks of earthquake occurred at Krasnojarsk in Siberia, during which a mountain in the neighborhood of that place was engulfed and a lake 300 feet in circumference and 180 feet deep in parts formed in its place. The water of the lake was sulphurous. As the country around was covered with ashes, it is probable that this event was connected with a volcanic eruption."

"A few weeks afterwards a similar lake of sulphurous water was formed near the mountain of Fajola, in the neighborhood of Rome where several severe shocks were felt at the time."

"St. Michaels in the Azores was visited by two severe earthquakes in 1811 and on both occasions they were accompanied by eruptions of a submarine volcano which threw dust, ashes and fragments of lava into the air. The points of eruption on the two occasions, were about two and a half miles apart; but neither of the craters ever appeared above water. These eruptions were attended by loud explosions."

"In December of that year commenced a long series of disturbances in the valley of the Mississippi, in Ohio and in Arkansas. These shocks continued at intervals till 1813 and were more distinguished by their frequency than their violence, which was, nevertheless, on several occasions very considerable. These long-continued earthquakes are the more remarkable from the circumstance that the countries affected by them are situated far from any volcano. The surface of the Mississippi valley was much altered by these convulsions, several new lakes forming while others were drained. New islands raised in the river and during one of the shocks the ground to the south of New Madrid was for a short time so uplifted as to stop the current of the Mississippi and cause it to flow backwards. The ground on which this town is built and the bank of the river for fifteen miles above it subsided permanently about eight feet and the cemetery of the town fell into the river. In the neighboring forest the trees were thrown into inclined positions and many of their trunks and branches were broken. It is affirmed that in some places the ground swelled into great waves which burst at their summits and poured forth jets of water with sand and pieces of coal which were tossed to the height of the trees. On the subsidence of these waves several hundreds of hollow depressions were left from ten to thirty yards in diameter and twenty feet in depth which remained visible many years. Some of the shocks were vertical, others horizontal, the latter being the most destructive. These earthquakes resulted in the general subsidence of a tract of country between seventy and eighty miles in length from north to south and about thirty miles in breadth from east to west."

I shall show how such quakes can be accounted for, and further that they have no direct relation to any volcano except that they have the same ultimate cause, *i.e.*, the gradual separation of the steam and other gases from the gaseous interior by secular cooling. The swelling of the ground into waves and the bursting of these waves at their summits, with the ejection of water and sand, as described, is due to the presence of gases which do not condense as did the steam. The escape of the gases was followed by subsidence and the formation of hundreds of hollow depressions.

"On the nineteenth of February, 1845, an earthquake occurred in New Granada, S. A., attended by peculiar circumstances. The shock was felt chiefly in the plain traversed by the Lagunilla, a small tributary of the river Magdalena, and was accompanied by much noise. Immediately after the shock a great flood of liquid mud was seen to issue from the ravine in which the stream rises. The mud flowed rapidly over the whole plain, carrying everything before it. Tall trees were swept down as if they had been straws, while houses and cottages with their inhabitants were overwhelmed. Only a few of them escaped to the mountains, unfortunately to meet a worse death by perishing with hunger, their place of refuge being unapproachable through the sea of mud. A small number who were near the edge of the torrent escaped over branches of trees. Forty square miles of land was covered by this muddy inundation."

"The north of Italy was much convulsed in March, 1846. The shocks were felt at Genoa and Leghorn where many houses were injured and some overthrown. Several villages throughout Tuscany were nearly destroyed and at Volterra a government prison fell, burying some of the prisoners in the ruins. There was considerable loss of life throughout Tuscany, and Pisa was severely shaken. The leaning tower is said to have rocked in a wonderful manner but was not injured. The vaulted roof, however, of an old church fell. The chief peculiarity in this earthquake was that, in several places jets of muddy boiling water sprang from the earth."

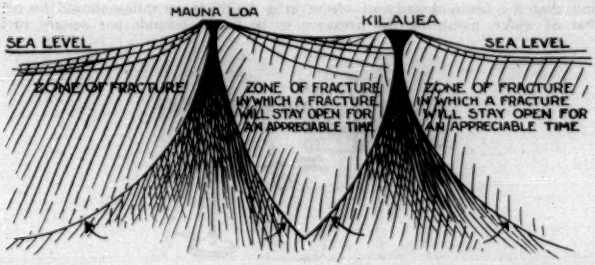
"On October ninth, 1857, in Illinois, there was a smart shock preceded by a remarkable electrical condition of the atmosphere, during which a luminous appearance was observed, described by some as a meteor and by others as a vivid flash of lightning."

This feature of the earthquake phenomena is noted in many cases and of course might simply be a coincidence, but is much more likely to be the effect of gases escaping into the air.

Many more accounts of interesting phenomena connected with earthquakes are contained in Mungo Ponton's book, and enough has been quoted to give the salient features and to show that the opening of fissures, the discharge of mud and sand from small craters, the discharge of sulphurous and other gases as well as the appearance and disappearance of hot springs accompany the more vigorous quakes. We now come to consider how these phenomena can be accounted for by the theory of a gaseous interior, or at least a zone in which matter is above its critical temperature.

Below the zone of solid flowage the zone of critical temperature extends to the centre of the earth. The temperature in this zone determines the

FIG. 1.


MAUNA LOA
KILAUEA
SEA LEVEL
SEA LEVEL
ZONE OF FRACTURE
ZONE OF FRACTURE IN WHICH A FRACTURE WILL STAY OPEN FOR AN APPRECIABLE TIME
ZONE OF FRACTURE IN WHICH A FRACTURE WILL STAY OPEN FOR AN APPRECIABLE TIME

A zone in which solids flow under temperature and pressure, in which a fracture is impossible, as it will close immediately, is called the zone of solid flowage and is probably 200 miles thick. Peaks in the zone of solid flowage denote supersaturation with steam and other gases and indicates lava pipes.*

gaseous condition of all of the matter composing it. By the power of diffusion it must remain homogeneous until a portion of it solidifies, when that portion separates from the portion still remaining gaseous.

Owing to the great pressure, the density of the gas is greater than the solid form, and for this reason the solid crust floats on the gaseous core like ice on water. Gases of low critical temperatures diffuse upward through

* The section of Hawaii is intended to convey the idea that there is no connection between Mauna Loa and Kilauea except through the zone of solid flowage at great depth, thus showing how they act independently of each other. The steam escaping through the liquid lava in the craters, causes the lava fountains to play and furnishes the heat to keep the lava fluid. Sea level is shown correctly according to sketch at about three miles below the top of Mauna Loa, Kilauea being 16 miles distant.

The diameter of the lava craters and pipes is exaggerated. It is fitting that this theory of the gaseous interior should be discussed in the Journal of the Franklin Institute, for Benjamin Franklin was the first to suggest it in 1784, as can be seen in the tenth volume of his life and letters in the library of the Institute.

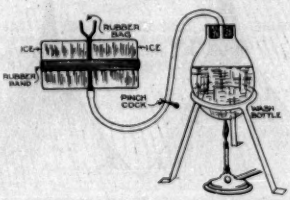
the zone of solid flowage until they reach the bottom of the zone of fracture, where they are stopped until they supersaturate it to such an extent that it has a high elastic force like a compressed spring.

When the tensional strain of the gases becomes great enough to rupture the zone of fracture, a fracture is formed and the supersaturated magma impelled by the steam and other gases rushes into it. The walls of the fracture are colder than the steam, which condenses and causes the fracture to close by reflex action, causing a shock or earthquake. The steam and other gases of low critical temperature which I shall call the magmatic steam, are not held in the zone of solid flowage by the power of diffusion as they were in the zone of critical temperature, but are forced up through this zone by difference of density multiplied by the depth.

For example, suppose that the mean density to a depth of ten miles is three times that of water. The pressure of water increases 0.44 of a pound per foot of depth, and three times that—1.32 pounds pressure per square inch per foot of depth, or 6970 pounds per mile, or 69,700 pounds pressure per square inch at a depth of 10 miles.

According to the formula for calculating the density of a gas which varies directly as the pressure and inversely as the absolute temperature, I find that the mean density of steam at a depth of 10 miles should be 0.65 that of water, assuming the pressure to be 69,700 pounds per square inch,

FIG. 2.



and the temperature to be 803 C. absolute (530 C. + 273 C.). According to this density, which is probably too high, the weight or pressure of a column of steam at a depth of 10 miles should be 15,100 pounds per square inch. Deducting this from 69,700 we get 54,600 pounds per square inch, or say 27 tons per square inch as the differential pressure acting on the steam at that depth to drive it up through the zone of solid flowage. The differential pressure at 100 miles would be ten times as great as at 10 miles and therefore it appears that at the bottom of the zone of solid flowage there is over 500 tons per square inch differential pressure.

Were it not for the high temperature and pressure and the fact that steam enters into the composition of silicates as a hydrous fusion at high temperatures, it is doubtful if even these high differential pressures could force it through. But by constant addition from below and relief from above the steam passes through the zone of solid flowage as through a porous diaphragm, and carries with it the heat necessary to make local fusions of the zone of fracture and discharge it as lava. The reason for calling the zone of solid flowage "solid," instead of "liquid," is, that the zone of critical temperature or gas zone is denser than the matter above it, or they would change places. If the gas expands on changing its state after cooling below the critical temperature, it would have to expand more to become a liquid than to become a solid, and the pressure is sufficient to prevent this, and therefore it takes a short cut and becomes a solid without becoming liquid. This expansion of the material in the zone of solid flowage is

evidently less than the contraction of the zone of critical temperature, or otherwise the earth would expand as a whole instead of contracting, as we know it does. The local expansion immediately below an earthquake that causes fractures to open is the tearing of the zone of fracture by the tensional pressure of the magmatic steam which has been accumulating for a long time under the differential pressure which drives it up through the zone of solid flowage. The quakes and tremors are not so much the result of the rupture as the result of the opening and closing of the fractures due to the intrusion and condensation of the steam. The non-condensing gases associated with the steam, pass on through to the surface and cause the peculiar atmospheric effects noted and alarm animals living in burrows, and cause sand and mud to be ejected, as in the New Madrid quake. When Professor Carter stated that 95 per cent. of all quakes were caused by faulting and slipping of the rocks, he stated only a part of the truth. The next question which would naturally follow would be what causes the faults and slips? Professor Carter would probably say, contraction and folding. But contraction and folding would cause overthrust and compression, and most certainly not cause cracks to open. The only cause competent to produce a crack or spread apart its walls is a local expansion immediately below the cracks. Now if we imagine that the zone of solid flowage has peaks and ridges on it,

FIG. 3.

just as the outer surface has, and that the magmatic steam collects in these peaks and ridges beneath the zone of fracture until it has sufficient expansive force to rip the zone of fracture, we can see why a fault plane once established will continue to act as an earthquake centrum for a long time without showing much displacement. The accumulation of magmatic steam throughout the thickness of the zone of solid flowage would have the effect of reducing its density, and if it should accumulate faster than it escaped through the zone of fracture then the surface must rise, and—on the contrary—if it escaped through the zone of fracture faster than it accumulated, then the density would increase and the surface must come down. Now that is just what happens in regions of rising such as the Andes, the density is less than it is under the ocean to the west where subsidence is taking place. It is no argument to say that the "earth's crust is in an unstable equilibrium," for it has had plenty of time to get into equilibrium. The question is, what disturbs the equilibrium?

A difference of 2 per cent. in density between two regions, if applied through the thickness of the zone of solid flowage (200 miles), would cause a difference of elevation of four miles, or 21,000 feet, and if by escape of the steam in one case and accumulation in the other the densities become reversed, the elevations will change with them. Professor Carter after having said that it is solid, speaks of the earth's crust breaking and caving in, as cause of earthquakes. This appears highly improbable, as on account of the great pressure, cavities could not exist.

The different kinds of vibrations which are found to occur in earthquakes can be explained by supposing that in case the fault plane is vertical, the opening and closing causes a horizontal movement, while if a sill of lava is being introduced horizontally between bedded rocks, the intrusion and condensation of the magmatic steam causes a vertical movement.

Figures 2 and 3 illustrate apparatus for producing shocks of both kinds. In the first experiment, boil the water in the wash-bottle and force the steam into the rubber bag which is held tightly between the cakes of ice by the rubber band around the two cakes. When the steam enters suddenly the rubber bag will be distended, the cakes forced apart and the band stretched. The steam will be condensed by the cold walls of the bag and the walls will come together with a shock. Turn the ice cakes so that the bag is horizontal and the shock will be vertical.

In the second experiment, boil the water and force steam into the inverted bell jar filled with water. The steam on entering will be condensed and cause a shock to the sheet-rubber cover to the top of the bell jar. Small objects placed on this sheet-rubber may be tossed about in a manner similar in earthquake shocks.

All the complicated phenomena of volcanic action—hot springs, geysers, mud volcanoes and ore deposition—can be explained by the theory herein set forth, but as Professor Carter treated on the subject of earthquakes only, which is but one of the many effects produced by magmatic steam, I will merely refer to other papers on the subject which I have written: "Relation of Magmatic Waters to Volcanic Action," JOURNAL OF THE FRANKLIN INSTITUTE, October, 1908; "A Theory of Volcanic Action and Ore Deposition," Institute of Mining and Metallurgy, London; "Magmatic Waters," Canadian Mining Institute, 1906.

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